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Effects of Varying Exercise Stress Upon Skin Temperature During Exercise and Through Recovery.

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by
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Dedication:

To my wife, Dianne, and
my children, Rick and Beth

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ABSTRACT

This study was conducted to determine whether variances in physical fitness would cause differences in skin temperature patterns during exercise and through a thirty minute recovery period. The primary purpose was to determine if the skin temperature patterns of high and low fitness groups would differ significantly during an exercise load at four heart rate dynalevels and through recovery from exercise. A secondary purpose was to determine whether a specific body location could be found that would indicate radiometry could be used to measure physical fitness.

Sixty male subjects were randomly selected to study the relationships between heart rate and skin temperature induced by exercise performed on a motor driven treadmill. High and low fitness groups were separated for additional study to determine whether differences and/or relationships were present due to the factor of fitness. The subjects were classified by the amount of time necessary for the heart rate to attain 180 beats per minute. Seven body locations were studied: forehead, a point immediately inferior to the sternum, belly of the left bicep, center of the left palm, tip of the left thumb, belly of the left rectus femoris, and belly of the left gastrocnemius.

Subjects were tested in a 72°F to 76°F environment by using a Barnes radiometer and a cardio-tach to obtain skin temperature and

heart rate. Resting skin temperature and heart rate measurements were taken after a fifteen minute rest period and were continued throughout the exercise phase as heart rates attained 120, 140, 160, and 180 beats per minute. Monitoring for skin temperature and heart rate were continued through the thirty minute recovery period at three minute intervals.

A split-plot factorial analysis of variance was used to determine whether differences existed in skin temperature changes at seven body locations among high and low fit groups due to the effects of exercise stress at various heart rates. An additional split-plot factorial analysis of variance was used to determine what effects recovery time had upon skin temperature changes experienced by high and low fitness groups. Curvilinear regression equations were employed to study the skin temperature and heart rate relationship for fitness groups and the total subject population at the seven body sites during exercise. This procedure was also used to study the relationships between skin temperature and time, and skin temperature and heart rate for both groups and the total subject population at all seven body locations through thirty minutes of recovery.

The results of this study showed that:

1. Low fit individuals experience lower skin temperature than highly fit individuals as exercise increases to maximal levels.

2. Highly fit individuals experience higher skin temperatures during recovery from exercise than low fit individuals.

3. There is evidence that the fitness level of an individual may be determined by measuring skin temperature at the center of the palm.

CHAPTER 1

INTRODUCTION

Seeking answers to the unknown has brought man through the ages to where he stands today. Man's present knowledge of technology has enabled him to conquer many barriers, including those of space travel. The technology and research programs of the United States enabled this country to develop a life support system so sophisticated that one could journey through thousands of miles to the moon in thermal conditioned comfort.[1] Yet, researchers have not conclusively solved the mystery of how the physiological makeup of man allows him to function actively and maintain a static inner core temperature.

Modern Science has been studying the effects of body temperature since the seventeenth and eighteenth centuries when a few pioneer physicians realized the values of such study.[2] But, it remained for the technicians of the twentieth century to offer researchers the equipment necessary to analyze this basic body function. Based on the knowledge that all objects emit infrared radiation, thermography

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[1]J. C. Chato and others, "On the Dimensionless Parameters Associated with Heat Transfer within Living Tissue," Aerospace Medicine, XLI (April, 1970), 390.

[2]J. E. Schmidt, Medical Discoveries (Springfield: Charles C. Thomas, 1965), p. 448; J. Gershon-Cohen and others, "Medical Thermography: A Summary of Current Status," Radiologic Clinics of North America, III (December, 1965), 403-31; C. Maxwell-Cade, "Principles and Practices of Clinical Thermography," Radiography, XXXIV (February, 1968), 23-34.

was developed to measure body temperature in a totally passive form. Used initially for detection of enemy hiding under cover of darkness, technology created an optics system that could provide a picture of an object's emitted rays.[3]

When thermography was declassified by the military in 1956, it was not long until researchers in medicine realized its possibilities. In 1957, a Baird Evaporograph[4] was used experimentally to detect breast cancer. Although encouraged by the results, physicians realized that technical limitations of the equipment were inherent, since the early systems were not designed for medical, clinical, or research work. However, second generation thermographs are now operational and provide researchers with far superior instrumentation to study temperature unknowns in man.[5]

The body of knowledge of skin temperature has increased rapidly with contributions from the medical profession and a few exercise physiologists. Since it is quite apparent that physicians are interested in thermography to detect abnormalities in man, it is left to the exercise physiologist to study the effects of activity on skin temperature in the normal exercising man. Commonly referred to as a virgin field even in medicine, the study of skin temperature in the active man is practically non-existent.

Man's knowledge of the effects of exercise upon heart rate and heart functions has been extensively documented in the literature

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[3] Ibid.

[4] Ibid., R. N. Lawson, "Early Applications of Thermography," Annals of the New York Academy of Sciences, CXXI (October, 1964), 31-33.

[5] Gershon-Cohen, pp. 403-31.

of exercise physiology.[6] An area of interest in this literature is the study of heart rate as a measure of cardiovascular fitness. In general terms, fitness levels may be measured by taking the pulse of one who has undergone a specific work load and with a mathematical computation using the pulse rate place the individual into a fitness level category. Through the development of various fitness tests the physical education profession has made a valuable contribution in the area of preventative medicine. In continuation of such efforts, research in skin temperature may provide an additional parameter to assess the physical fitness of an individual.

Five studies related to the effects of exercise on skin temperature were found. One study showing the effects of exercise on the relationship between heart rate and skin temperature was found.

Saltin et al.[7] conducted a study of muscle temperature during submaximal exercise in man. It was found that the quadriceps muscle temperature of the four subjects studied increased during exercise while the skin temperature decreased.

Loiselle[8] while studying various physiological parameters during exercise, based upon one pre- and post-test measurement of skin

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[6] Per Olof Astrand and Kaare Rodahl, Textbook of Work Physiology, (New York: McGraw-Hill, 1970), pp. 117-21, 147-73, 343-50; Laurence E. Morehouse and Augustus T. Miller, Jr., Physiology of Exercise, Fifth Edition, (St. Louis: C. V. Mosby, 1967), pp. 97-104; Peter V. Karpovich and Wayne E. Sinning, Physiology of Muscular Activity, Seventh Edition, (Philadelphia: W. B. Saunders, 1971), pp. 202-11; Herbert A. de Vries, Physiology of Exercise, (Dubuque: W. C. Brown Company, 1966), pp. 72-79.

[7] B. Saltin and others, "Muscle Temperature During Submaximal Exercise in Man," Journal of Applied Physiology, XXV (December,1968),679-88.

[8] Denis Loiselle, "The Effects of Varied Environments on Selected Physiological Variables," (unpublished master's thesis, University of Alberta, 1966), pp. 14-54.

temperature, found a lower skin temperature directly over exercising quadriceps muscle when compared with the average skin temperature of twelve subjects.

It was determined by Potanin _et al._[9] that the onset of angina pectoris during exercise was associated with coolness at specific sites of the chest and arms. This study stated that thermography could evaluate and predict the onset of angina pectoris.

Lynch _et al._[10] used a thermograph recorder to study forearm skin temperature in an attempt to measure forearm skin blood flow in twelve subjects. While one arm remained static, the other was subjected to an isometric work load. This study concluded that there was no difference in skin temperature between limbs after exercise.

Using twenty-four subjects to conduct a similar study with more controls, O'Connell[11] found a significant difference in skin temperature in favor of the working arm.

In attempting to shed light upon the mystery of exercise heart rate, Harris and Porter[12] conducted a study to investigate the

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[9] C. Pontanin and others, "Thermographic Patterns of Angina Pectoris," _Circulation_, XLII (August, 1970), 199-204.

[10] P. R. Lynch and others, "Results of Studies Using Two Radiological Methods in Investigating the Circulation of Exercising Human Arms," _Journal of Physiology_, CCXIII (March, 1971), 41P-42P.

[11] Eugene R. O'Connell, "The Effects of Local Isometric Muscular Activity on Local Skin Temperature," _Journal for the Association for Physical and Mental Rehabilitation_, XIV (May-June, 1960), 74-75.

[12] E. A. Harris and B. B. Porter, "On the Heart Rate During Exercise, Esophageal Temperature and the Oxygen Debt," _Quarterly Journal of Experimental Physiology_, XLIII (July, 1958), 313-19.

possible relationship between heart rate and chemical factors. The researchers subjected one individual to a series of eight exercise bouts while recording esophageal temperature, heart rate, and oxygen debt. The results of this study led to the belief that a rising deep body temperature may be responsible for cardiac acceleration after five minutes of exercise in the steady state.

Statement of the Problem

This study was conducted to determine if levels of physical fitness would cause differences in skin temperature patterns during exercise stress and through a thirty minute recovery period.

Purpose of the Study

The primary purpose of the study was to determine if the skin temperature patterns of high and low fitness groups would differ significantly during exercise stress and through recovery from exercise.

A secondary purpose was to study the skin temperature patterns during exercise and through recovery of selected body locations to determine if a specific site could be found to measure levels of physical fitness.

Definition of Terms

Heart Rate. Heart rate was determined by the pulse count obtained from an exercise cardio-tachometer.[13]

Skin Temperature. The skin temperature was the radiant temperature recorded by the Barnes Medical Thermometer[14] on a target area

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[13]Manufactured by the Quinton Instrument Company, Seattle, Wash.

[14]Manufactured by the Barnes Engineering Company, Stamford, Connecticut.

one-tenth of an inch in diameter when the instrument's nose cone was held one-quarter of an inch from the surface of the skin.

Radiometer. The Barnes Medical Thermometer was called a radiometer.

Exercise Load. Exercise load was defined as work performed on a treadmill,[15] set at four miles per hour with a twenty percent grade, with pauses made long enough for a thirty second monitoring period when the heart rate reached 120, 140, 160, and 180 beats per minute.

Low and High Fit Subjects. The elapsed time that each of the sixty subjects took to attain a heart rate of 180 beats per minute was used for placement into either high or low fitness groups. The low fitness group was comprised of the subjects with the shortest times to attain 180 beats per minute; whereas, the high fitness group was made up of those subjects that possessed the longest times to attain a heart rate of 180 beats per minute.

Dynalevels. A dynalevel represents a relative heart rate attained by a subject while performing the exercise load on the treadmill. These dynamic heart rate levels were 120, 140, 160 and 180 beats per minute.

Delimitations of the Study

The subjects selected for the study consisted of sixty undergraduate students enrolled at Louisiana State University, Baton Rouge

[15]Manufactured by the Quinton Instrument Company, Seattle, Washington.

Campus. The ages of the subjects ranged between 18 and 30 years. Data were collected during the summer and fall semesters of 1973.

Testing sessions were limited to one period per subject. The attainment of four dynalevels was determined by the visual display counter of the cardio-tach and the monitoring time was limited to thirty seconds. Testing was conducted between 3 - 7 P.M. daily to control circadian rhythm differentials in skin temperature which fluctuate readily throughout a twenty-four hour span.

Limitations of the Study

The subjects were requested to refrain from eating, drinking, and smoking for at least four hours prior to testing. Vigorous exercise was to be avoided on the testing day. It was not possible to ensure that all sixty subjects abided by the requested guidelines.

To monitor the seven body locations during exercise it was necessary to have the subject stop exercising for thirty seconds at each dynalevel. This procedure caused the time for the subject's heart rate to attain the final dynalevel to be greater than it would normally require the subject to attain 180 beats per minute.

It was felt that motivational factors were kept to a minimum since the treadmill exercise was largely submaximal and the subject received a thirty second rest after attaining each dynalevel.

Significance of the Study

A need for additional basic information regarding skin temperature changes in normal individuals and those with physiological abnormalities was expressed in the literature covering skin temperature research.[16] This study was conducted to provide basic information regarding variables in skin temperature patterns between highly fit and unfit individuals undergoing exercise stress. In addition, this study was conducted to determine if a particular body location could be used to detect variances in skin temperature to a degree that may enable the determination of an individual's level of fitness. Such monitorings of skin temperature either during or after submaximal exercise would provide researchers and evaluators of physical conditioning with a rapid means of determining physical fitness.

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[16]James F. Connel, Jr., and others, "Thermography in Trauma," Annals of the New York Academy of Sciences, CXXI (October, 1964), 171-6; Travis Winsor and Jesus Bendezu, "Thermography and the Periferal Circulation," Annals of the New York Academy of Sciences, CXXI (October, 1964), 135-55; H. L. Karpman, "Current Status of Thermography," Angiology, XXI (February, 1970), 103-109.

CHAPTER 2

REVIEW OF RELATED LITERATURE

The review of literature studied in preparation for the investigation covered: (a) information related to the history of thermography; (b) readings related to the physics of thermography; (c) studies covering the physiology of skin temperature; (d) recent information related to medical studies and applications of thermography; and (e) studies related to exercise and skin temperature. The chapter is concluded with a summary of the review.

Literature Related to the History of Thermography

In 1626 the first recorded clinical use of a thermometer[1] was conducted by Santorius Sanctorius, an Italian physician. Gabriel Fahrenheit, a German physicist, introduced the mercury thermometer graduated into 180 degrees in 1714. The Swedish astronomer, Anders Celsius invented the Centigrade thermometer in 1714. The modern clinical thermometer was developed in 1817, by the English physician Thomas Allbutt.

Thermography[2] was actually an extension of thermometry. Sir William Herschel, an eminent English astronomer, reported in 1800,

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[1] J.E. Schmidt, Medical Discoveries, (Springfield: Charles C. Thomas, 1959), p. 448.

[2] J. Gershon-Cohen and others, "Medical Thermography: A Summary of Current Status," Radiologic Clinics of North America, III (December, 1965), 404; C. Maxwell-Cade, "Principles and Practice of Clinical Thermography," Radiography, XXXIV (February, 1968), 23-24.

his observation of certain rays beyond the red end of the visible spectrum. Herschel named these rays, "infrared." This finding was noted with little interest and lay dormant until Sir John Herschel, his son, rendered the infrared spectrum visible by developing crude pictures termed "thermographs." Sir John Herschel's work was also largely ignored until 1929, when Czerny expanded and improved the thermographic process and named it "evapography." At approximately the same time as Sir John Herschel's work, Becquerel discovered that infrared radiation would stimulate phosphorescent afterglows which could be excited in certain minerals by visible or ultraviolet light.

In 1949, Urbach, Nail, and Pearlman[3] presented two methods of fluorescence thermography based upon Becquerel's studies. The first, Contact Thermography, involved direct contact of phosphors with the object to be examined. The second, Projection Thermography, involved optical projection of heat radiation from the object onto a phosphorescent screen.

The use of heat radiation[4] to see in darkness and through camouflage was of interest to the military in the United States, England, and Russia. The United States military establishment became interested in infrared emissions as early as 1919, when Hoffman published a paper on the "Detection of Invisible Objects by Heat Radiation."[5] By 1932, the U.S. Signal Corps Engineering

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[3] *Ibid.*, p. 23.

[4] *Ibid.*, pp. 23-24.

[5] R. N. Lawson, "Early Applications of Thermography," *Annals of the New York Academy of Sciences*, CXXI (October, 1964), 31.

Laboratories were studying the effects of infrared emissions. However, between 1932 and 1956 when the Baird Evapograph was declassified, military applications related to infrared emissions were highly classified. Access to a Barnes thermographic scanner was obtained by Lawson for medical application studies in 1957.

The American Thermographic Society was formed in June of 1967, with ten members. By June of 1968, the registration in the society had increased to over fifty members.[6]

Literature Related to the Physics of Thermography

Four physical processes by which heat is released from the body were reviewed: convection, evaporation, conduction, and radiation.

Convection

Convection[7] is described as a transfer of heat through a moving fluid. When a body surface is warmer than the environmental air temperature, heat will flow from the body to the surrounding air. As the air becomes heated it will rise and be replaced by cooler air. Because of this flow, cooler air moves continuously upward to the body surface, becoming warmed by the heat convected and then

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[6]H. L. Karpman, "Current Status of Thermography," Angiology, XXI (February, 1970), 106.

[7]Theodore C. Ruch and Harry D. Patton, Eds. Physiology and Biophysics, Nineteenth Edition, (Philadelphia: W. B. Saunders, 1965), 1052.

flow away. Heat loss as a result of convection depends upon the existence of a temperature gradient between the body surface and ambient air. If the surface and air are the same temperature, there is no convective heat transfer. The gradient can be altered in either direction providing an increase or decrease in surface temperature.

Evaporation

The total evaporative heat loss from transcutaneous diffusion and respiratory ventilation is minor for an individual resting in a cool thermal environment.[8] About fifteen percent of the total heat loss is known as "insensible perspiration." In a warm environment evaporation becomes the dominant factor in heat exchange because the active secretion of sweat greatly increases the water availability for evaporation at the surface of the body.

Conduction

Conduction depicts a loss or increase in surface temperature due to physical contact of the body with some environmental object. It was pointed out that in any material, heat tended to flow down a temperature gradient by transfer of thermal energy between adjacent atoms. It is known that the tissues of the body are not very good heat conductors. Thus, if the heat exchange within the body was conductive, large internal temperature gradients would be necessary to conduct metabolic heat flow from the body. Therefore, convective heat transfer was reported as the major means of

[8] Ibid., pp. 1052-55.

transferring internal heat through the body to the exterior environment.[9]

Radiation

Various physiologists have shown that heat loss from the body surface via radiation may be accurately measured by the use of thermography.[10] The skin surface was found to be a nearly perfect absorber and emitter of infrared energy.[11] For the physical purposes of studying infrared emissions, a single number was assigned to describe the qualities of an object to absorb or emit infrared energy. Hence, something with an emissivity of 1, the ideal "black body", absorbs all the energy incident upon it and emits the maximum amount consistent with its temperature.[12]

Several physiologists[13] have shown that human skin is a nearly perfect absorber and emitter of infrared energy with an accepted

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[9] Ibid.

[10] Gershon-Cohen, pp. 404-5; Maxwell-Cade, pp. 23-24; R.B. Barnes, "Thermography," Annals of the New York Academy of Sciences, CXXI (October, 1964), 34-47; E. E. Brueschke, "Infrared Thermoprofile Analysis in Clinical Medicine," American Journal of Medical Electronics, IV (ND, 1965), 65; J. W. H. Mali, "Some Physiological Aspects of the Temperature of the Body Surface," Proceedings of a Boerhaave Course for Postgraduate Medical Education, 1969, 1-16.

[11] Gershon-Cohen, pp. 404-5.

[12] Ruch and Patton, p. 1053.

[13] R. B. Barnes, "Determination of Body Temperature in Infrared Emission," Journal of Applied Physiology, XXII (June, 1967), 1143-6; D. J. Watmough and R. Oliver, "Emissivity of Human Skin in Vivo Between 2.0 μ and 5.4μ Measured at Normal Incidence," Nature, CCXVIII (June, 1968), 886; Maxwell-Cade, pp. 23-24; D. Mitchell and others, "Emissivity and Transmittance of Excised Human Skin in Its Thermal Emission Wave Band," Journal of Applied Physiology, XXIII (September, 1967), 390-3.

emissivity of 0.989. This level of emitted radiation is not affected by skin color.

The theoretical operation of obtaining skin temperature measures through the use of radiometry was presented by Karpman.[14] The author states that the infrared emissions given off by the human body have radiant energy which can be collected optically, transformed into electronic impulses, amplified, synthesized, and presented in a final thermal image.

Literature Related to the Physiology of Skin Temperature

Physiology of Skin Temperature

Chato *et al.*[15] studied the physical and physiological parameters associated with heat transport within living tissue. The purpose of the study was to analyze the thermal behavior of living humans. The skin surface area, depth of tissue, thermal conductivity, density, and specific heats were considered part of the physical parameters; whereas total metabolic rate, heat generation per unit volume in living tissue and the blood perfusion rate per unit volume were considered physiological parameters.

Using a model of 63 kilogram adult male with a mean arterial blood pressure of 90 mm Hg and a total metabolic rate of 85 watts, Chato *et al.*, through mathematical computations, concluded that the

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[14] Karpman, "Current Status of Thermography," p. 103.

[15] J. C. Chato and others, "On the Dimensionless Parameters Associated with Heat Transport within Living Tissue," *Aerospace Medicine*, XLI (April, 1970), 390-3.

maximum body temperature can occur in the muscle tissue and is dependent upon perfusion rate. Occurrence of a maximum temperature in the tissue would be directly related to the inclusion of blood flow "since all heat generated in the body is assumed to be removed at the skin, both heat flowing toward the inner core and heat generated in the inner core must be transported by blood toward the skin."[16]

Chapman and Mitchell[17] believed that the blood flow to the muscle is increased during exercise. The flow to the skin may also be increased, either because of an increasing body temperature or by heating the skin by underlying exercising muscles.

The results of a study conducted by Saltin *et al.*[18] appear to refute writings of Chapman and Mitchell regarding changes in skin temperature during exercise. Saltin *et al.* while working with four subjects showed that skin temperature decreased during exercise.

Best and Taylor's writings[19] on medical physiology included their opinions on body heat. These authors stipulated that the rate of blood flow through the skin is the principle regulator in determining heat loss from the body. This view was also found in the writings

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[16] *Ibid.*, p. 392.

[17] Carleton B. Chapman and Jere H. Mitchell, *The Physiology of Exercise*, (New York: Scientific American, 1965), I-72.

[18] B. Saltin and others, "Muscle Temeprature during Submaximal Exercise in Man," *Journal of Applied Physiology*, XXV (December, 1968) 679-88.

[19] Charles H. Best and Normal B. Taylor, Eds., *The Physiological Basis of Medical Practice*, Seventh Edition, (Baltimore: Williams and Wilkinson Company, 1961), 884.

of other physiologists.[20]

Fan et al., [21] while reviewing mathematical models of the human thermal system, pointed out that heat generated by metabolic reactions inside the body is either stored within the body or transferred to the skin surface by two means: conduction through bones, tissues, fat, and the skin; and by convection accomplished through blood circulation. This point was also supported by Mali.[22]

Astrand and Rodahl[23] have written that blood possesses a high heat capacity and is capable of carrying large amounts of heat with just a moderate increase in temperature.

Abramson[24] has stipulated that the skin of both the palm and plantar surface of the foot are primarily sites of heat loss from the body through convective transfer of the high blood flow within these two anatomical sites.

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[20] J. D. Hardy, "Physiology of Temperature Regulation," Physiological Reviews, XLI (July, 1961), 521-606; Lawrence M. Baker and William M. Taylor, "The Relationship under Stress between Changes in Skin Temperature, Electrical Skin Resistance, and Pulse Rate," Journal of Experimental Psychology, XLVIII (May, 1954), 361-66; R. B. Barnes, "Determination of Body Temperature in Infrared Emission," Journal of Applied Physiology, XXII (June, 1967), 1143-6; W. J. B. M. van der Staak, "Experiences with the Heated Thermocouple," Dermatologica Basel, CXXXII (ND, 1966), 192-205; Chato and others, pp. 390-3.

[21] Liang-Tseng Fan and others, "A Review on Mathematical Models of the Human Thermal System" Bio-Medical Engineering, XVIII (May, 1971), 218-234.

[22] Mali, pp 8-16.

[23] Per Olof Astrand and Kaare Rodahl, Textbook of Work Physiology, (New York: McGraw-Hill Book Company, 1970), 492.

[24] David I. Abramson, Circulation in the Extremities, (New York, Academic Press, 1967), 240.

Abramson, Allen and Baker stated that variation in relative humidity has little effect on heat loss from the body at normal room temperature.[25]

Smith and Mansfield _et al._ have presented evidence of the existence of circadian rhythms in body temperatures which fluctuate readily throughout a twenty-four hour period.[26]

Gershon-Cohen _et al._[27] mentioned that heat losses due to sweating would not occur below 30°C. In their opinion heat losses below this temperature were due to radiation and convection.

Procedural Techniques in the Use of Thermography

Gershon-Cohen _et al._,[28] in reviewing accepted techniques in the use of thermography, emphasized that although the internal temperature of the human body remains essentially unchanged at 37°C, the skin temperature may fluctuate widely due to many factors. These were reported as "structural abnormalities of vessels, abnormalities of vascular control, local effects on vessels from systemic reactions, changes in thermal conductivity of the tissues, and increased heat production in the tissues."

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[25] _Ibid._, Edgar Allen and Hines Baker, _Pheripheral Vascular Disease_, (Philadelphia: W. B. Sanders, 1947), p. 102.

[26] R. E. Smith, "Circadian Variations in Human Thermoregulatory Responses," _Journal of Applied Physiology_, XXVI (May, 1969), 557; C. M. Mansfield and others, "A Comparison of the Temperature Curves Recorded over Normal and Abnormal Breasts," _Radiology_, XCIV (March, 1970), 697.

[27] Gershon-Cohen, pp. 411-12.

[28] _Ibid._, pp. 405-411.

In outlining the preliminary procedures involved in taking skin temperature measurements various writers emphasized that the body should be exposed nude for ten to fifteen minutes in a controlled ambient temperature of 65-75°F. A rest period is necessary to ensure that skin temperature will come into equilibrium with the ambient air and maximize the display of temperature differences.[29]

Roth _et al._, summarized by Allen and Baker,[30] showed that changes in posture influenced skin temperature of the extremities. This statement was based upon the observation that skin temperature of the toes and fingers decreased when the extremities were elevated and increased when lowered.

Mali[31] observed that small changes in the radiating surface caused by small movements can have effects upon skin temperature, as does the geometrical location and distance to the surrounding walls and solid structures.

Literature Related to Medical Studies and Applications of Thermography

Initial medical interest in thermography began in 1957, when researchers determined that breast carcinoma could be detected by thermography.[32]

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[29]Barnes, "Thermography," p. 45; Gershon-Cohen, pp. 411-12; H.L. Karpman and others, "Clinical Status in Thermography. II. Applications of Thermography in Evaluating Musculoligamentous Injuries of the Spine -- A Preliminary Report," _Archives of Environmental Health_, XX (March, 1970), 413.

[30]Allen and Baker, p. 102.

[31]Mali, pp. 11-19.

[32]K. Lloyd Williams, "Infrared Thermometry as a Tool in Medical Research," _Annals of the New York Academy of Sciences_, CXXI (October, 1964), 100; Brueschke, p. 65.

In 1965, Gershon-Cohen et al.[33] presented skin temperature data of thermagraphic findings of one hundred cases of cancer in 464 patients screened for breast pathology. Of the 464 patients, 214 normal patients evidenced bilateral symmetry. Four of the 100 who were diagnosed as having breast cancer had less than 1°C difference between symmetrical sites and the remaining 96 patients' readings indicated asymmetry greater than 1°C.

Clinical observations conducted in 1968, showed evidence of breast asymmetry up to 4°C occurring without pathological significance. This was apparently due to the differences in many women whose breasts differ in vascularity as well as size. However, distinct differences were noted in patterns found between asymmetry due to tumor or absess or to differences in vascularity.[34]

Mansfield et al.[35] conducted a study in 1970, which compared Farenheit temperature curves recorded over normal and abnormal breasts during a twenty-four hour period. The two normal cases studied displayed bilaterally symmetrical readings throughout the twenty-four hour period. Three patients harboring malignancies produced asymmetrical readings with the cancerous breast always several degrees higher during the twenty-four hour period.

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[32] K. Lloyd Williams, "Infrared Thermometry as a Tool in Medical Research," Annals of the New York Academy of Sciences, CXXI (October, 1964), 100; Brueschke, p. 65.

[33] Gershon-Cohen, p. 417.

[34] Maxwell-Cade, p. 28.

[35] Mansfield, pp. 697-8.

Connell et al.[36] presented preliminary information regarding the use of the Barnes Thermograph and a radiometer in studying various trauma situations. These investigators studied burn patients, surgical wounds, traumatic wounds, sprains, and traumatic arthritis. The opinions of the investigating team were enthusiastic over the potential of thermography and radiometry for the medical profession.

Winsor and Bendezu,[37] also utilizing the Barnes Thermograph and radiometer, presented a study to show some of the applications of thermography in the study of peripheral circulation. Some of the areas included thrombophlebites, arteriosclerosis, Raynauld's disease, trauma to the extremities, and smoking and circulation. The investigators believed that the future of thermography appears unlimited and encouraged studies of circulation as well as other areas.

Thermography also has been used to diagnose carotid arterial disease. Price[38] indicated that findings of abnormality in thermographic measurements were highly significant with respect to the presence of carotid occlusive vascular disease.

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[36]James F. Connel, Jr., and others, "Thermography in Trauma," Annals of the New York Academy of Sciences, CXXI (October, 1964), 171-6.

[37]Travis Winsor and Jesus Bendezu, "Thermography and the Periferal Circulation," Annals of the New York Academy of Sciences, CXXI (October, 1964), 135-55.

[38]Thomas R. Price and others, "Correlation of Thermography and Angiography in Carotid Arterial Disease: Thermographic Measurements as a Screening Technique," Neurology, XX (April, 1970), 398.

The use of thermography and radiometry also has been utilized in studying the unknowns of Hansen's disease and related areas of associated trauma.[39]

Advantages in using a Barnes radiometer were reported in a new clinical procedure used in detecting varicose veins and venous insufficiency.[40] Prior to the use of radiometry, approximately fifty skin temperature readings were made with a thermistor thermometer in a time consuming procedure. The use of radiometry greatly facilitated the time involved in the preparation and monitoring of the patients. The writers believed that their reported technique appeared sufficiently simple and reliable for routine clinical work.

Albert *et al.*[41] published a preliminary report on the uses of thermography in various spheres of orthopedics. Brief case studies were reported with corresponding pictorial thermographic presentations of: trauma, degenerative disc disease, avascular necrosis of bone, neoplastic lesions, and inflammatory aberrations in bone and soft tissues.

Additional areas of medicine are presently under investigation utilizing thermography: placental location, early detection of

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[39] Thomas D. Sabin, "Temperature-linked Sensory Loss," *Archives of Neurology*, XX (March, 1960), 257-62; D. Ray Collins, "A Comparison of the 'Slipper-Sock' Footprint Test and the Harris Footprint Test as Possible Indices for Prediction of Skin Temperature Changes of the Feet," A paper read at the Social Rehabilitation Service Research Staff Meeting at the U.S. Public Health Hospital, Carville, Louisiana, April 13, 1971.

[40] Norman Rosenberg and Anastassios Stefanides, "Thermography in the Management of Veins and Venous Insufficiency," *Annals of the New York Academy of Sciences*, CXXI (October, 1964), 113-17.

[41] S. M. Albert and others, "Thermography in Orthopedics," *Annals of the New York Academy of Sciences*, CXXI (October, 1964), 157-70.

pregnancy, industrial and occupational medicine, rheumatism and arthritis, and urology.[42]

Literature Related to Exercise and Skin Temperature Studies

Previous observations of angina pectoris, and the suggestion that regional vasoconstriction does occur during pain of angina, prompted Potanin, et al.,[43] to use liquid crystals as skin temperature sensors in studying fifty male patients with past history of angina pectoris. The patients were exercised on a treadmill to induce angina pectoris. Of the fifty subjects, 28 remained free of pain and their thoracic thermograms were unchanged in pre-and post-test measurements. The investigators noted that 22 patients developed angina pectoris during exercise; 21 had associated ST depression in the electrocardiogram and 17 abnormal thermographic profiles. In 9 patients, where the pain was unilateral, skin coolness was localized in the area of pain. Skin coolness was not within the area of pain in 8 of 13 patients whose pain was central. Upon relief of pain, skin temperature returned to normal. The authors believed that thermography has potential as an objective method of assessing the presence of angina pectoris. Furthermore, it may become possible to anticipate the onset of angina.

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[42] Gershon-Choen, p. 431; Karpman, "Current Status of Thermography," pp. 103-9.

[43] C. Potanin and others, "Thermographic Patterns of Angina Pectoris," Circulation, XLIII (August, 1970), 199-204.

Saltin *et al.*[44] conducted a study of muscle temperature during submaximal exercise in man. Four subjects with maximal oxygen uptake levels ranging from 3.87 to 5.17 liters per minute were subjected to a two week training program. The subjects trained on a bicycle ergometer for one to two hours every day. Quadriceps muscle temperature was measured by thermocouples inside Teflon catheters six centimeters deep and by needle probes which were used only during short rest periods. The Teflon catheters were inserted in the lateral portion of the quadriceps muscle about fifteen centimeters above the patella. Skin temperatures were measured during rest and exercise at approximately five minute intervals at ten locations: the hand, forearm, upper arm, cheek, upper back, lower back, chest, abdomen, thigh, and calf. An infrared radiometer was used to measure skin temperature.

Pedal frequency of a bicycle ergometer was kept at fifty revolutions per minute by use of a metronome. All subjects performed in ambient temperatures of 10, 20, and 30°C. The resting measurements were taken five minutes after the subject entered the test chamber. The subjects also performed at submaximal work loads of 25, 50, and 70 percent of their maximal oxygen uptake. The authors reported the following results: both legs evidenced bilaterally symmetrical skin temperatures; resting muscle temperatures were generally lower than rectal temperature; exercise skin temperature gradually dropped approximately 2° C during the first ten minutes of exercise and

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[44]Saltin, pp. 679-88.

remained rather constant thereafter; and average skin temperature during exercise was usually 1°C lower than over the active thigh muscles.

Lynch *et. al.*[45] used a thermographic recorder to study forearm skin temperatures in an attempt to measure forearm skin blood flow. Thermograms of twelve subjects were recorded, with one hand maintaining a ten percent maximum voluntary contraction on a handgrip ergometer while the other hand performed no work. The thermograms ranged from 33°C to 36°C. In two subjects the exercising arm was 1°C warmer, in four subjects the arm was about 1°C cooler. There were no differences among the remaining subjects. The authors concluded that exercise had no major consistent effect on blood flow in the overlying skin. The procedures used provided no rest period and the authors stated that all twelve subjects had worked for "some hours" before participating in the experiment.

O'Connell[46] found that the effects of local isometric muscular activity of the forearm flexor muscles caused a significant increase in skin temperature. With twenty-four subjects and the left arm serving as a control, thirty maximal contractions of the right forearm flexor muscles were performed for a one minute period on two different occasions. Skin temperatures made over the belly of the biceps muscle by a thermistor thermometer were recorded before

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[45] P. R. Lynch and others, "Results of Studies using Two Radiologocal Methods in Investigating the Circulation of Exercising Human Arms," *Journal of Physiology*, CCXIII (March, 1971), 41P-42P.

[46] Eugene R. O'Connell, "The Effect of Local Isometric Muscular Activity on Local Skin Temperature," *Journal for the Association for Physical and Mental Rehabilitation*, XIV (May-June, 1960), 74-75.

exercise and three minutes afterwards. In each of the two sessions it was found that both arms increased in skin temperature with the increase in the right arm significantly higher.

Loiselle[47] studied the effects of varied thermal environments on several selected physiological parameters, including skin temperature, upon twelve subjects exercising on a bicycle ergometer. Skin temperature of the quadreceps femoris was compared with the average skin temperature of six other anatomical points on the body. Copper constantan thermocouples were used to record skin temperature data between the fifth and sixth minute of exercise. The investigator concluded: skin temperature overlying active muscles was lower than the average temperature; skin temperature increased with humidity; and skin temperature increased with higher humidity and temperature.

In an attempt to determine how heart rate increases during exercise, Harris and Porter[48] designed a study to investigate the possible relationship between heart rate and body chemical factors. The investigators considered it necessary to monitor temperature changes, heart rate, alveolar CO_2 tension, and esophageal temperature. Data were collected on a single subject performing ten minute bouts on a treadmill set at three and four miles per hour at zero percent grade. The subject performed at gradients of 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0 percent while the speed on the treadmill

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[47] Denis Loiselle, "The Effects of Varied Thermal Environments on Selected Physiological Variables," Microcarded Master's thesis, University of Alberta, 1966, pp. 14-54.

[48] E. A. Harris and B. B. Porter, "On the Heart Rate during Exercise, Esophageal Temperature and the Oxygen Debt," _Quarterly Journal of Experimental Physiology_, XLIII (July, 1958), 313-19.

was set at four miles per hour. After each exercise the subject rested for twenty minutes. Temperature measurements were made with a copper constantan thermocouple located in the esophagus immediately behind the left atrium. Heart rate was measured with a cardio-tach. The authors were uncertain whether this arrangement gave a true measure of the left atrial temperature, but concluded that a rising deep body temperature after five minutes of exercise in the steady state may be responsible for cardiac acceleration.

Summary of Related Literature

The history of thermography dates from the first clinical use of a thermometer in 1626, to present day applications in every phase of medicine.[49] Interest in infrared radiation was stimulated by the military during the first part of this century. When the military declassified the Baird Evapograph in 1956, researchers in medicine began applying the infrared theory to detect breast cancer.[50]

The four ways that heat is dissipated from the body were reviewed.[51]

The theoretical operation of thermography was reviewed. The literature indicated that rays emitted via radiation from the body

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[49] Schmidt, p. 448.

[50] Gershon-Cohen, pp. 403-31; Maxwell-Cade, pp. 23-34; Lawson, pp. 31-33.

[51] Barnes, "Thermography," pp. 34-47; Mitchell, pp. 390-3; Ruch and Patton, p. 1052; Gershon-Cohen, pp. 404-5.

could be collected optically, transformed into electronic impulses, amplified, synthesized, and presented in a final thermal image.[52]

The literature presented many studies relating to skin temperature physiology. It was postulated that maximum body temperature can occur in the muscle and is dependent upon blood profusion rate and this heat is transported by the blood toward the skin.[53] A proposed theory, which hypothesized an increase in skin temperature during exercise, was in contrast with results of a controlled experiment measuring skin temperature during exercise.[54] There was evidence of a circadian rhythm in variations of skin temperature measured during a twenty-four hour period.[55]

Literature relating to techniques in the use of thermographic equipment was reported.[56] To ensure proper results in skin temperature monitoring, the following suggestions were presented: subjects should be exposed from ten to fifteen minutes in an ambient temperature ranging from 65-75°F; body movement should be kept to a minimum; changes in body posture should be minimized; subjects should refrain from smoking and eating for at least three hours; and subjects should avoid strenuous exercise prior to experimental study.

The medical profession used thermography to study skin temperature variations in patients afflicted with various physiological

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[52]Karpman, "Current Status of Thermography," p. 103-9.

[53]Chato, pp. 390-3; Best and Taylor, p. 884; Hardy, pp. 521-601; Baker and Taylor, pp. 361-6.

[54]Chapman, p. I-72; Saltin, pp. 679-88.

[55]Smith, p. 557; Mansfield, p. 697.

[56]Mali, pp. 11-19; Barnes, "Thermography," p. 45; Karpman, "Clinical Studies in Thermography...," p. 413; Gershon-Cohen, p. 404.

abnormalities. Samples of these were: breast cancer, burns, surgical wounds, traumatic diseases, arteriosclerosis, various vascular diseases, orthopedics, Hansen's disease, placental location, urology, and industrial and occupational medicine.[57]

The exact effects of exercise upon skin temperature remains questionable. Of four studies reviewed relating to the effect of exercise upon skin temperature, three concluded there was a drop in skin temperature[58] while one indicated that there was no difference.[59]

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[57]Williams, p. 100; Gershon-Cohen, p. 417; Maxwell-Cade, p. 28; Mansfield, pp. 697-8; Brueschke, p. 65; Connel, pp. 171-6; Winsor, pp. 135-55; Rosenberg, pp. 113-17; Albert, pp. 157-70; Sabin, pp. 257-62; Karpman, "Current Status of Thermography," pp. 103-9.

[58]Saltin, pp. 679-88; O'Connell, pp. 74-75; Loiselle, pp. 14-54.

[59]Lynch, pp. 41P-42P.

CHAPTER 3

PROCEDURE FOR THE STUDY

Overview of Procedures

Sixty subjects were used to study the relationships between heart rate and skin temperature induced by exercise dynalevels performed on a motor driven treadmill. High and low fitness groups were derived for additional study to determine whether selected differences and/or relationships were present due to the factor of fitness. The relationships under investigation dealt with measurements of heart rate and skin temperature prior, during, and after a walk on a treadmill at four miles per hour at a twenty percent incline. Seven anatomical sites located along the frontal plane and left side of the body were selected for skin temperature measurement. Since the literature substantiated that bilateral symmetry[1] existed in normal man, monitoring of both sides of the body was not necessary. This monitoring procedure allowed the investigator to increase the scope of the study by selecting more anatomical sites while keeping the monitoring time to a minimum of thirty seconds.

During the laboratory testing period the electrodes of the cardio-tach were attached to the chest and sternum area of the

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[1]Normal F. Boas, "Thermography in Rheumatoid Arthritis," Annals of the New York Academy of Sciences, CXXI (October, 1964), 223-34; C. M. Mansfield and others, "A Comparison of the Temperature Curves Recorded over Normal and Abnormal Breasts," Radiology, XLIV (March, 1970), 897-8; B. Saltin and others, "Muscle Temperature during Submaximal Exercise in Man," Journal of Applied Physiology, XXV (December, 1968), 697-88.

subject's body. The seven anatomical sites for radiometer monitoring were marked with a felt pen. The subject was then seated for a fifteen minute rest period. The resting heart rate was recorded along with the seven resting skin temperature measurements. The subject began walking on the treadmill and when the heart rate attained 120, 140, 160, and 180 beats per minute, the subject stopped exercising long enough to be monitored.

After the last monitoring period, the subject was seated to undergo a thirty minute rest period. The subject was advised to be as still as possible. At three minute intervals heart rate and skin temperature measurements were monitored and recorded. Upon completion of the tenth measuring period, the subject was excused.

A split-plot factorial analysis of variance was used to determine whether differences existed in skin temperature changes at seven body locations among high and low fitness groups due to the effects of exercise stress at various heart rates. An additional split-plot factorial analysis of variance was used to find out what effects recovery time had upon skin temperature changes experienced by high and low fitness groups. Curvilinear regression equations were employed to study the skin temperature and heart rate relationship for fitness groups and the total subject population at the seven body sites during exercise. Curvilinear regression equations were used to study the relationships between skin temperature and time and skin temperature and heart rate for both groups and the total subject population at all seven body locations through thirty minutes of recovery.

Personnel Required to Conduct the Study

One lab assistant was employed to assist with collection of skin temperature and heart rate data. The assistant was thoroughly indoctrinated in the procedures developed to collect the data and was responsible for time monitoring and data recording. The author was responsible for the skin temperature monitorings which were conducted in accordance with the procedures recommended by the Barnes Manufacturing Company.

Selection of Subjects

Sixty male subjects were selected to participate in this study. The ages of the subjects fell within a range of eighteen to thirty years. The subjects were selected from the general university population in attendance during the summer and fall sessions of 1973, at Louisiana State University, Baton Rouge, Louisiana. The investigator personally met with the students and sought volunteers to participate in the study.

Grouping of Subjects

During several of the statistical analyses fifteen subjects classified as high fit and fifteen as low fit were separated for additional study. The criterion for measuring the high and low fitness levels within the sixty subject sample was the amount of time necessary for the heart rate of a subject to attain 180 beats per minute. The subjects with the lowest times (2:22-4:38 minutes) were placed in the low category and those with the longest times (8:00-15:12 minutes) comprised the high group.

Testing Apparatus

Stop Watch. One stop watch was used for time measurements before, during, and after exercise performed on the treadmill.

Radiometer. The Barnes Model MT-3 Medical Thermometer was used to measure the skin temperature of the seven body locations selected for investigation. The radiometer has a response time of 2 seconds in the slow response mode and .2 seconds in the fast mode. The sensitivity of the instrument has been determined to be .1°C in the slow and .25°C in the fast mode. Throughout this study the fast response mode was used. The radiometer has the capacity of providing either Fahrenheit or Centigrade readings with a temperature range of 20 to 40°C or 65 to 105°F. The Centigrade scale was used during this study in keeping with previous studies of this nature. The recommended field of view was stated to be .1 inch at .25 inches from the nose cone to the skin surface. Physical contact was not necessary and the radiometer did not influence the actual skin temperature of a subject at the time of measurement.

The radiometer consisted of two basic components: the sensing head which houses the radiation collecting mechanisms and a signal preamplifier; and the electronics console which consists of the readout system and power supply. The operating manual suggested that the radiometer should be operational for approximately thirty minutes before data collecting if maximum reliability is desired.

Treadmill. A Quinton treadmill, Model 18-49C, was used as the exercise inducing instrument in this study. The treadmill could provide speeds between one and ten miles per hour and elevations from zero to forty percent.

Cardio-tach. Model QI-609 Exercise Cardio-tachometer was designed to obtain accurate heart rate measurements during vigorous exercise. The cardio-tach has two components. The isolation preamplifier provided shielded leads that attached to the body and were driven by two nine volt batteries. The preamplifier was coupled to the main display panel by a standard phone plug. The second component consisted of the control and display unit. This unit provided instantaneous or twenty second averaging of heart rate data.

Voltmeter. A voltmeter was used to test the voltage levels of the two batteries used on the isolation preamplifier. The proper functioning of the cardio-tach depended upon a voltage of no less than 8.4 volts per battery.

Thermometer. An indoor thermometer was placed within the testing area to ensure that the room temperature was maintained within a range of 72 to 76°F.

Resting Chair. The resting chair used was a standard wood office chair with a padded back. During monitoring periods the subject's arms were allowed to hang down along side of the body in a relaxed manner.

Procedures for Measuring Skin Temperature and Heart Rate Before, During, and After Treadmill Walk

Procedures Employed Before the Treadmill Walk

The following procedures were used to collect data prior to the beginning of exercise:

1. Each day before the first subject reported to the laboratory, the equipment was checked. The radiometer was operational 30 minutes prior to the arrival of the first

subject.

2. When the subject arrived, the investigator ensured that he was clothed with shorts, socks, and shoes. Also, the following information was recorded on the data sheet: name, age, height, weight, and room temperature. To facilitate a counterbalanced testing procedure the data sheet was marked to indicate whether the measuring began superior or inferior to the transverse plane of the body.
3. The subject was then marked with a felt pen at those sites to be monitored by the radiometer. These areas in terms of the anatomical position were: a point immediately above the nose and in the center of the forehead along the anterior aspect of the sagittal plane; a point located immediately inferior to the sternum near the transpyloric plane; the belly of the left bicep brachii; immediate center of the left palm; a central point on the tip of the left thumb; belly of the left rectus femoris; and belly of the left gastrocnemius. Appendix B provides a pictorial description of the above defined locations.
4. The investigator informed the subject that the treadmill would be set at a speed of four miles per hour with a twenty percent grade and that he would walk pausing long enough for a thirty second monitoring period when the heart attained 120, 140, 160, and 180 beats per minute.
5. The subject was seated in the resting chair with the cardio-tach electrodes attached to the subject's chest. The stop watch was started to begin a fifteen minute rest

period. Emphasis was placed on ensuring that the subject remained as still as possible. Upon conclusion of the rest period, the watch was reset and started after the resting skin temperature and heart rate data was monitored and recorded.

Procedures Employed During the Treadmill Walk

The following procedures were adhered to during the exercise phase of the study:

1. Upon completion of the initial monitorings, the subject began the treadmill walk. The lab assistant began the watch and observed the subject's heart rate on the cardiotach. Once the desired dynalevel was attained, the subject moved to the stationary platform of the treadmill and while standing erect was monitored for skin temperature. The running time for the subject to attain the dynalevel was recorded by the lab assistant. The sites were monitored perpendicular to the body surface and 1/4 inch away from the skin.
2. These procedures were repeated for the remaining dynalevels.
3. The stop watch was reset to begin timing the thirty minute recovery period when the subject's heart rate attained 180 beats per minute.

Procedures Employed after the Treadmill Walk

The final monitoring session was conducted in the following manner:

1. Monitoring of skin temperature and heart rate data continued

at three minute intervals for thirty minutes.

2. After all measurements were recorded, the subject was detached from the cardio-tach and excused.

Pilot Study

The author served as a lab assistant in a similar study conducted by Gantt[2] in order to become familiar with the testing apparatus and procedures employed in monitoring skin temperature.

A major purpose of the pilot study was to determine whether significant skin temperature decreases during exercise and increases through recovery at particular body locations were evident after a four mile per hour walk on the treadmill at a twenty percent incline. Ten subjects were studied under these conditions. T-tests for significance of the difference between correlated means were utilized to analyze the negative mean gains of the ten subjects from the resting to the lowest measured temperature recorded at the seven locations during exercise. It was found during the exercise phase that significant negative mean gains at the .01 level of probability were evident at the head, heart, bicep, palm, thumb, and rectus femoris. Temperature loss at the gastrocnemius was significant at the .05 level of probability. Each of the seven areas appeared to have undergone enough stress from the selected work load.

Similar t-tests were computed between the initial skin temperature and the peak temperature reached during recovery from exercise.

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[2]Robert B. Gantt, "Bilateral Comparisons of Skin Temperatures of Uninjured and Postoperative Knees Before and After Exercise," Unpublished Master's thesis, Louisiana State University, Baton Rouge, Louisiana, 1972, pp. 1-65.

The results showed that temperatures of the head, heart, palm, thumb, rectus femoris, and gastrocnemius were significant at the .01 level of probability. The bicep data was not significant.

Additional factors which the pilot study showed were: monitoring could be controlled at a constant thirty second period; subjects who showed initial irregularities in cardio-tach heart rate monitoring required adjustments in placing the electrode lead attached on or above the sternum; and it was found that the cardio-tach was not responsive with some individuals.

Statistical Analysis

The data that were statistically analyzed in this study comprised pre-exercise measures of heart rate and skin temperature; exercise heart rate and skin temperature; and recovery heart rate, skin temperature, and time.

For the investigation of the effects of exercise dynalevels upon changes in skin temperature by fitness groups at the seven body locations a two-by-five-by-seven split-plot factorial analysis of variance was used. The high and low fitness groups comprised the main level A, five dynalevels made up level B, and the level C consisted of the seven body locations.

A two-by-ten-by-seven split-plot factorial analysis of variance was used to study skin temperature changes during recovery from exercise. The fitness levels comprised level A, ten monitorings of skin temperature spaced at three minute intervals through thirty minutes of recovery comprised level B, and level C consisted of seven body locations.

The final analysis used curvilinear regression equations to determine what type of relationships existed at the seven body locations: between the dependent variable skin temperature and independent variable heart rate for the fitness groups and the total subject population during the exercise phase of the study; and between skin temperature, heart rate, and time for the fitness groups and the total subject population during the recovery phase where skin temperature was treated as a dependent variable.

CHAPTER 4

PRESENTATION AND ANALYSIS OF DATA

A split-plot factorial analysis of variance was used to determine whether differences existed in skin temperature changes at seven body locations among high and low fitness groups due to the effects of exercise stress at various dynalevels. An additional split-plot factorial analysis of variance was used to find out what effects recovery time had upon skin temperature changes experienced by high and low fitness groups. Curvilinear regression equations were employed to study the skin temperature and heart rate relationship for fitness groups and the total subject population at the seven body sites during exercise. Curvilinear regression equations were used to study the relationships between skin temperature and time and skin temperature and heart rate for both groups and total subject population at all seven body locations through thirty minutes of recovery.

Analysis of the Effects of Exercise Dynalevels Upon Skin Temperature Scores of Fitness Groups and Body Locations

The analysis of variance of skin temperature scores attained by the high and low fitness subjects who experienced exercise at the various dynalevels is presented in Table 1. Graphic presentations, Figures 1 through 8, covering the statistical analyses may be found in the text. See pages 42, 44, 46, 49, 51, 53, 55, and 57. Additionally, the mean data utilized in the analysis of variance and related supplementary analyses may be found in Appendixes C, D, E, and F.

Comparison of Skin Temperature Scores from Rest through Four Dynalevels

The analysis of data showed a significant difference in skin temperature among the five dynalevels. Table 1 reveals an F-ratio of 71.84 with 4 and 112 degrees of freedom; this was significant at the .01 level of probability. Figure 1 depicts the skin temperature changes of all thirty subjects from the resting rate through the four exercise dynalevels. To determine whether linear characteristics of the curve were significant, orthogonal comparisons were employed. These comparisons, as shown in Table 2, indicated that the slope of the curve in Figure 1 was significantly linear at the at the .01 level of probability. The C_2 comparison showed a significantly quadratic characteristic at the .01 level of probability. Both fitness groups experienced a linear decrease in skin temperature from the resting rate through 180 beats per minute, the range in skin temperature being 31.62°C at rest and 30.93°C at the final dynalevel. The quadratic trend in the curve occurred between the beginning of exercise stress, 31.62°C, through a heart rate of 140 beats per minute, 31.08°C, after which a leveling off period occurred.

Interaction of Fitness Groups During Exercise Dynalevels and Skin Temperature Scores

The A X B interaction of the difference between the high and low fitness groups during the conditions of rest and performance through the four dynalevels was significant at the .05 level of probability. See page 41. The F-value was 2.40 with 4 and 112

Table 1

Analysis of Variance of Exercise Dynalevels and Skin Temperature Scores of High and Low Fitness Groups at Seven Body Locations

Source of Variance	Sum of Squares	df	Mean Square	F	P
A Group (High and Low Fit)	4.68	1	4.68	.11	NS
Individuals	1239.05	28	44.25		
B[a] Heart Rate (Rest and Four Dynalevels)	66.60	4	16.65	71.84	.01
AB[b] Interaction	2.23	4	.56	2.44	.05
Individuals Heart Rate Group	25.96	112	.23		
C[c] Location (Seven Body Sites)	529.66	6	88.28	160.31	.01
AC Interaction	5.15	6	.86	1.56	NS
BC[d] Interaction	29.45	24	1.23	2.23	.01
ABC Interaction	17.31	24	.72	1.31	NS
Residual	462.55	840	.55		
Corrected Total	2382.63	1049			

[a] P at .01 = 3.51

[b] P at .05 = 2.44

[c] P at .01 = 2.82

[d] P at .01 = 1.81

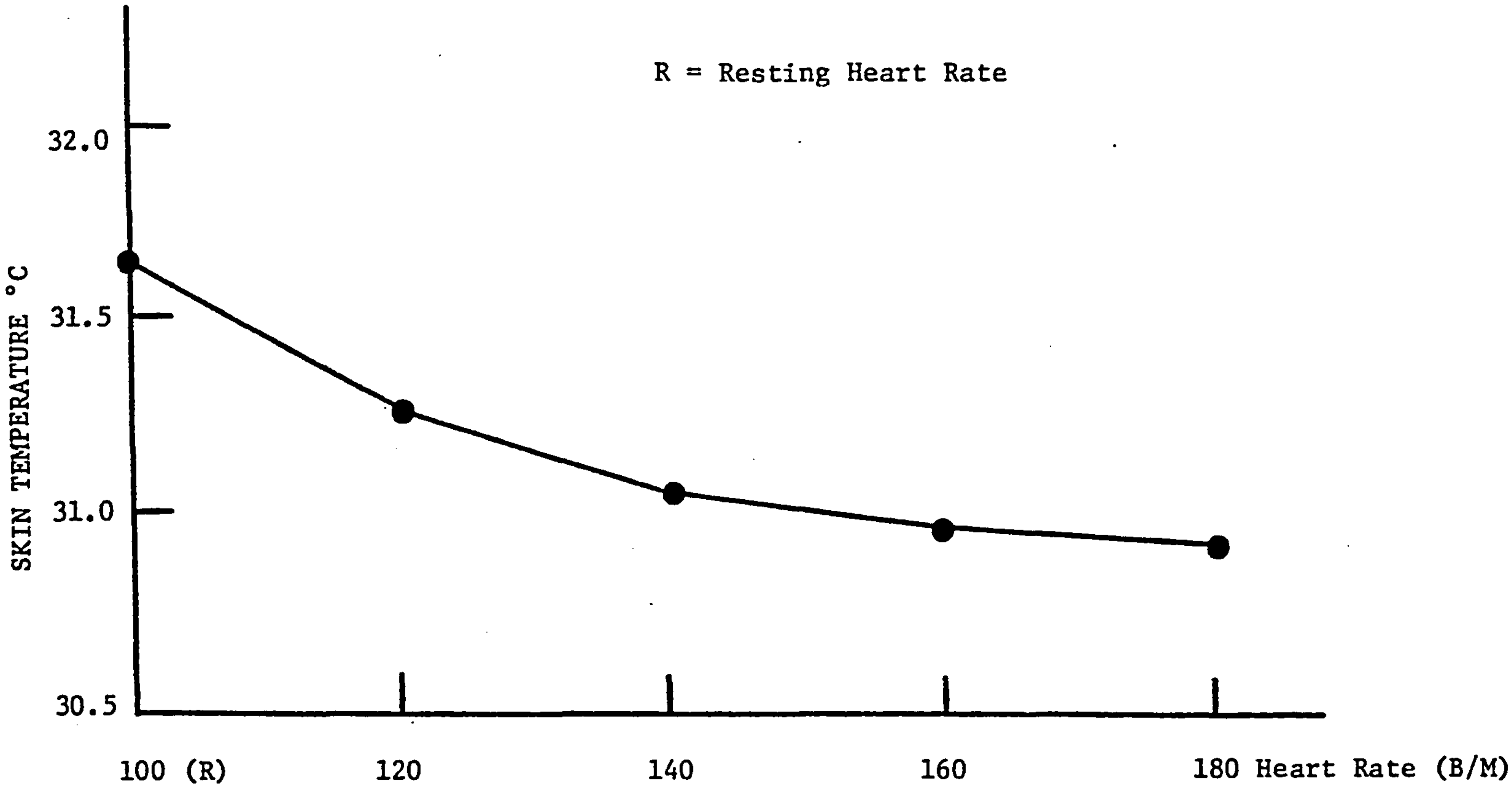

Figure 1

Mean Skin Temperature Experienced by Both Fitness Groups at Rest and Through Four Dynalevels

Table 2

Orthogonal Test for Linearity

Source of Variance	Sum of Squares	df	Mean Square	F	P
(From Part B of Table 1)					
Between	66.60	4	16.65	71.84	.01
Within	25.96	112	.23		
C_1Linear[a]	58.06	1		252.44	.01
C_2Quadratic[a]	8.08	1		35.13	.01

[a]P at .01 = 6.87

degrees of freedom. Both high and low fitness groups evidenced a parallel decreasing trend from the resting rate to 160 beats per minute. See Figure 2. At this point the low fitness group's temperature continued to decrease through 180 beats per minute to 30.76°C. The attainment of a maximal work load caused the skin temperature of the high fitness group to begin a return to normal while it continued to drop for the low fitness group.

Comparison of the Effects of Exercise upon the Differences Obtained in Skin Temperature Scores of the Seven Body Locations

The test for significance in Table 1 for skin temperature changes at the seven body locations shows that an F-ratio of 160.31 with 6 and 840 degrees of freedom was significant at the .01 level of probability. Figure 3 graphically displays the comparisons between locations. A Tukey test, Table 3, was used to determine

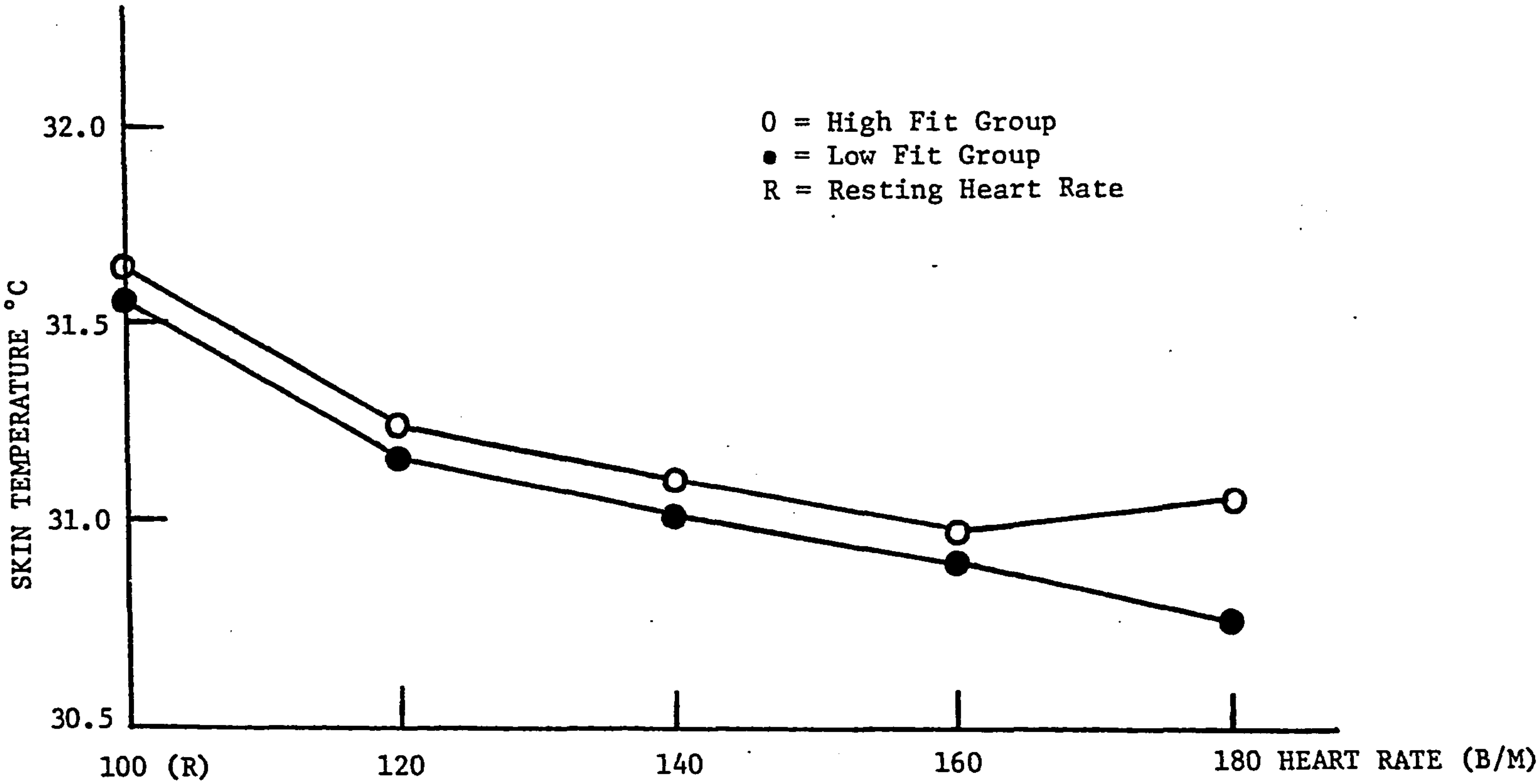

Figure 2

Mean Skin Temperature of High and Low Fitness Groups
at Rest and Through Four Dynalevels

the location of significance. Of the seven locations studied the head was the greatest emitter of heat during exercise, 32.43°C, while the thumb emitted the least, 29.91°C. The heart location was significantly greater than the thumb and less than the head location. Results of the Tukey test also indicated that no differences existed between the following sites: heart, bicep, rectus femoris, gastrocnemius, and the palm.

<u>Interaction of Exercise Dynalevels upon Differences in Skin Temperature Scores by Location</u>

The B X C interaction between the exercise dynalevels and body locations was significant. Figure 4 graphically demonstrates the deviation from uniformity of the differences among the seven body locations.

Analysis of the Recovery Times for Skin Temperature Scores Upon Fitness Groups and Body Locations

<u>Comparison of Skin Temperature Scores through Ten Periods of Recovery Time</u>

Table 4 shows an analysis of variance of the influence of recovery time on skin temperature taken at seven body locations of high and low fitness groups. A significant difference was found for level B, the ten monitoring periods. An F-value of 42.30 with 9 and 252 degrees of freedom was significant at the .01 level of probability.

Figure 5 shows skin temperature changes of all thirty subjects from the beginning of recovery through thirty minutes after exercise. Orthogonal C_1 and C_2 comparisons were made to determine if the curve was significantly linear. The C_1 comparison indicated that the slope of the curve was significantly linear at the .01

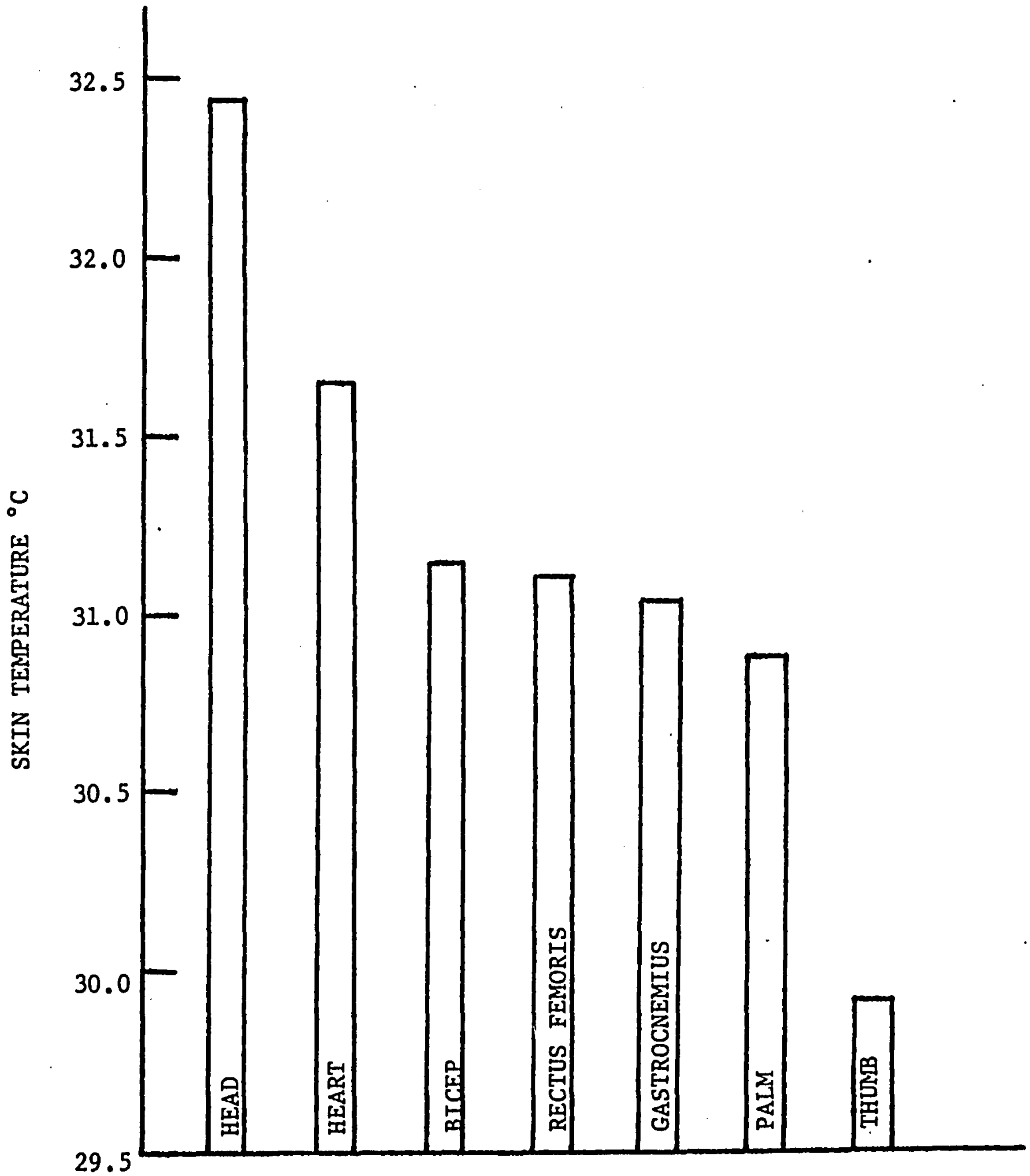

Figure 3

Mean Skin Temperature of Various Body Locations
Experienced by Both Fitness Groups
during Exercise

Table 3

Honestly Significant Differences Resulting from Tukey Test Comparing Skin Temperature Changes by Body Locations During Exercise

		Thumb	Palm	Gastroc-nemius	Rectus Femoris	Bicep	Heart
Location	T_s °C	29.91	30.88	31.02	31.12	31.13	31.65
Head	32.43	2.52[a]	1.55[a]	1.41[a]	1.31[a]	1.30[a]	.78
Heart	31.65	1.74[a]	.77	.63	.53	.52	
Bicep	31.13	1.23[a]	.26	.12	.01		
Rectus Femoris	31.12	1.22[a]	.25	.11			
Gastroc-nemius	31.02	1.11[a]	.14				
Palm	30.88	.97[a]					
Thumb	29.91						

[a]P at .01 = .92

Table 4

Analysis of Variance of Recovery Time Upon Skin Temperature Scores of High and Low Fitness Groups at Seven Body Locations

Source of Variance		Sum of Squares	df	Mean Square	F	P
A	Group (High and Low Fit)	63.34	1	63.34	.92	NS
	Individuals	1929.01	28	68.89		
B[a]	Time (Ten Monitoring Periods)	92.30	9	10.26	42.75	.01
AB[a]	Interaction	5.45	9	.61	2.54	.01
	Individuals/Time Group	61.10	252	.24		
C[b]	Location (Seven Body Locations)	439.81	6	73.30	172.95	.01
AC[b]	Interaction	31.51	6	5.25	12.39	.01
BC	Interaction	15.94	54	.30	.70	NS
ABC	Interaction	7.18	54	.13	.31	NS
	Residual	712.04	1680	.42		
	Corrected Total	3357.68	2099			

[a]P at .01 = 2.28

[b]P at .01 = 2.80

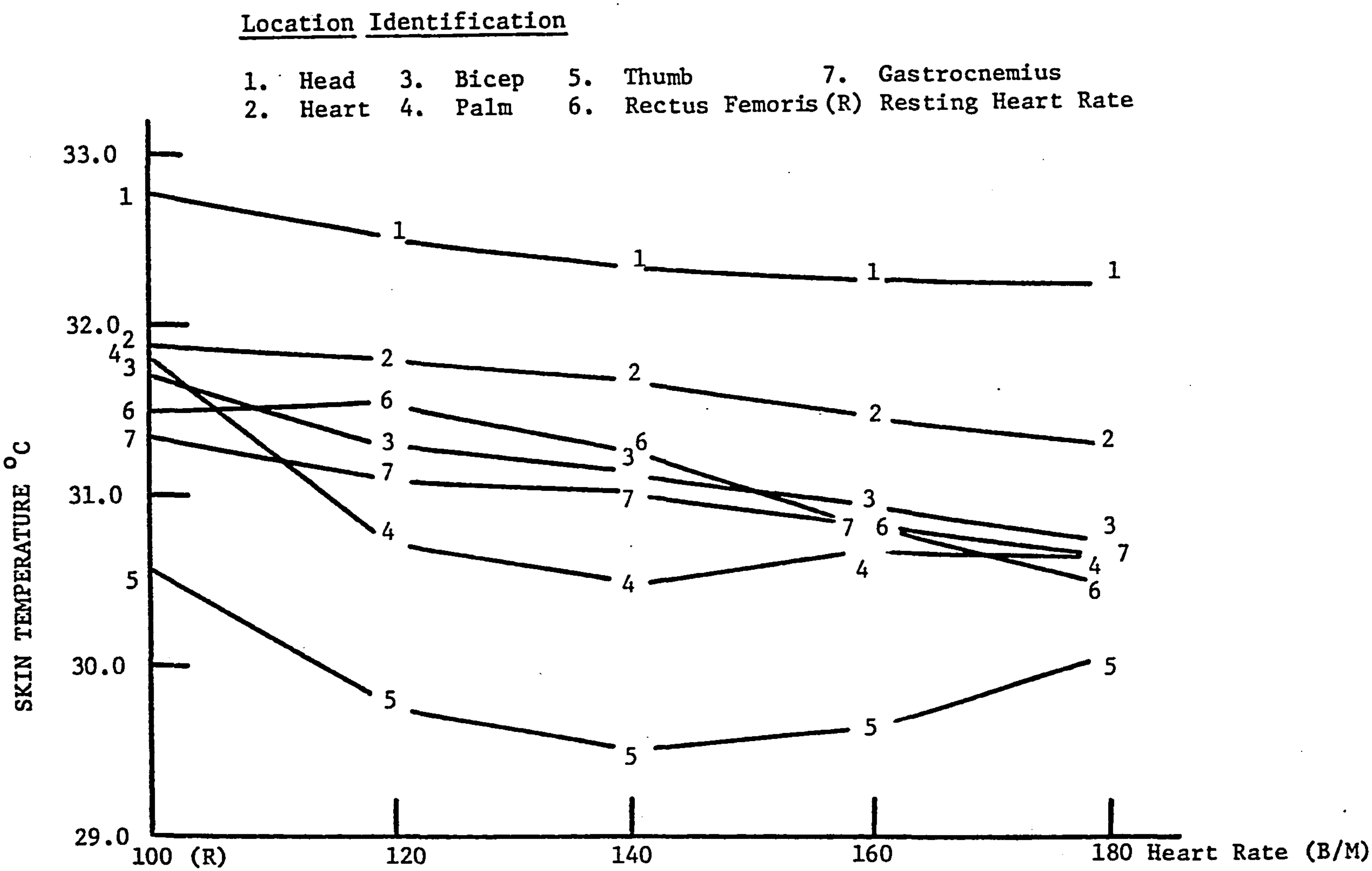

Figure 4

Mean Skin Temperature of the Body Locations of Both Fitness Groups from Rest Through Four Dynalevels level of probability. See Table 5. Also, the C_2 comparison showed that a significant quadratic characteristic was evident in the curve. This characteristic appears at the end of the recovery period.

Table 5

Orthogonal Test for Linearity

Source of Variance	Sum of Squares	df	Mean Square	F	P
(From Part B of Table 4)					
Between	92.30	9	10.26	42.30	.01
Within	61.10	252	.24		
C_1 Linear[a]	76.28	1		317.83	.01
C_2 Quadratic[a]	17.57	1		73.21	.01

[a]P at .01 = 6.74

<u>Interaction of Skin Temperature Between High and Low Fitness Groups and Recovery Intervals</u>

A significant interaction between the high and low fitness groups and the ten recovery time intervals was found. Refer to Table 4. Figure 6 displays a corresponding increase in skin temperature between the two fitness groups during the initial stages of recovery. In the last half of the recovery monitoring a divergence occurred between the two groups. While the high fitness group continued a linear trend, the low fitness group began to level off.

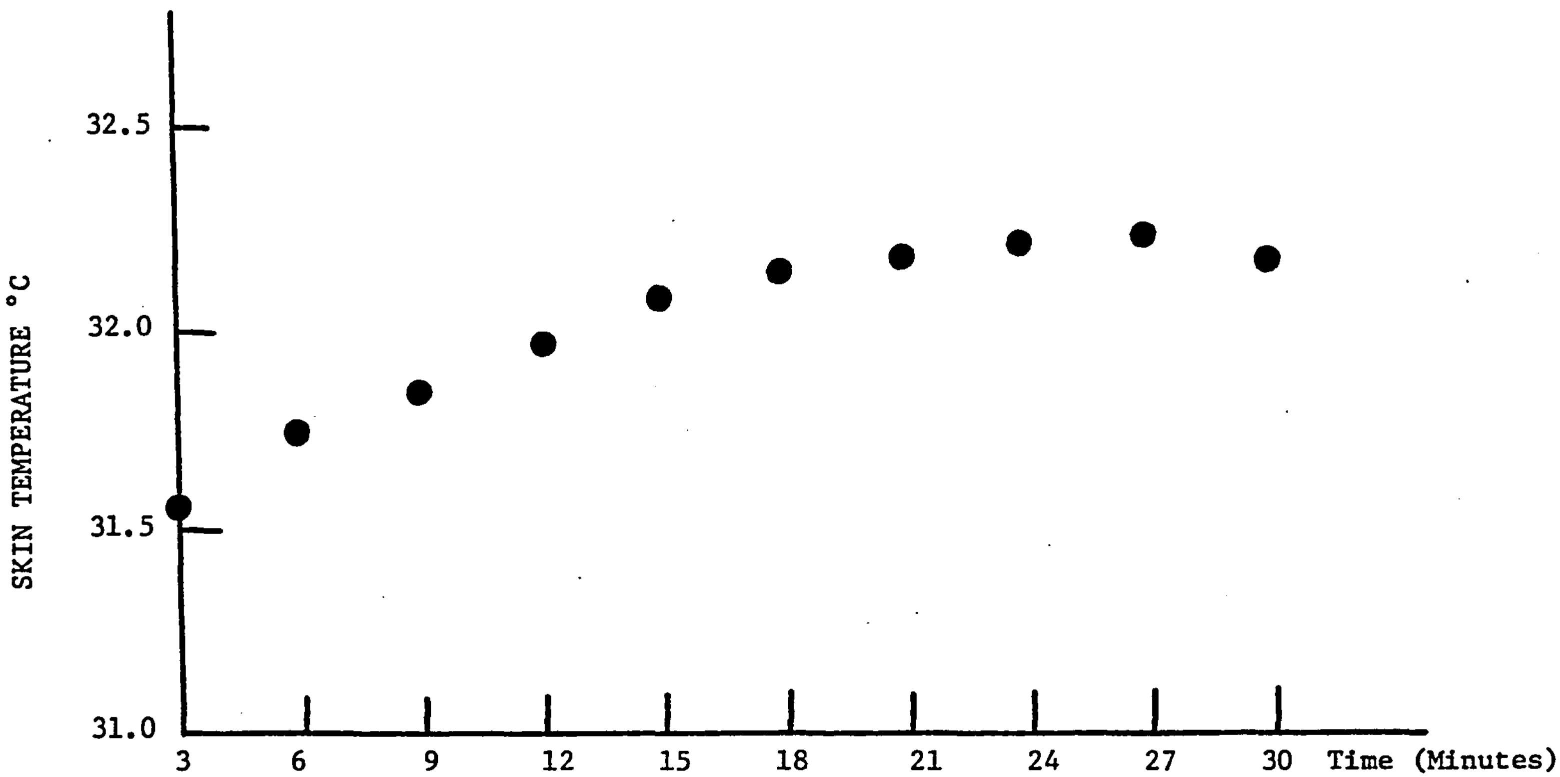

Figure 5

Mean Skin Temperature Experienced by Both Fitness Groups
Through Recovery from Exercise

Comparison of Changes in Skin Temperature among Body Sites during Recovery from Exercise

Comparing skin temperature scores by location, factor C, yielded a significant F-ratio. See Table 4 page 48. Comparisons among body locations were made by using the Tukey test. The results may be found in Table 6.

The results of the Tukey test revealed that the palm and head areas were high emitters of body heat with readings of 32.56°C and 32.85°C respectively. The gastrocnemius, rectus femoris, and biceps had temperatures ranging from 31.59°C to 31.70°C. The thumb, 31.90°C, was significantly lower than the palm, 32.56°C, and head, 32.85°C. The skin temperature of the heart area was significantly lower than the palm and head and higher than the gastrocnemius. See Figure 7.

Interaction Between High and Low Fitness Groups and Changes in Skin Temperature by Body Location during Recovery from Exercise

A comparison of the ranges in skin temperature during a thirty minute recovery period does not change uniformly in regard to body locations for either group. See Figure 8. Recovery of the low fitness group, although not uniform, was lower in skin temperature in six locations when compared to the high fitness group. The heart area was the only location where the temperatures of the low fitness group were higher than the high fitness group, 31.82°C versus 31.77°C respectively.

A Tukey test, Table 7, was conducted to determine where significant divergences from uniformity in the skin temperature ranges occurred between the fitness groups during recovery. The results of this analysis indicated that the divergence between groups at the

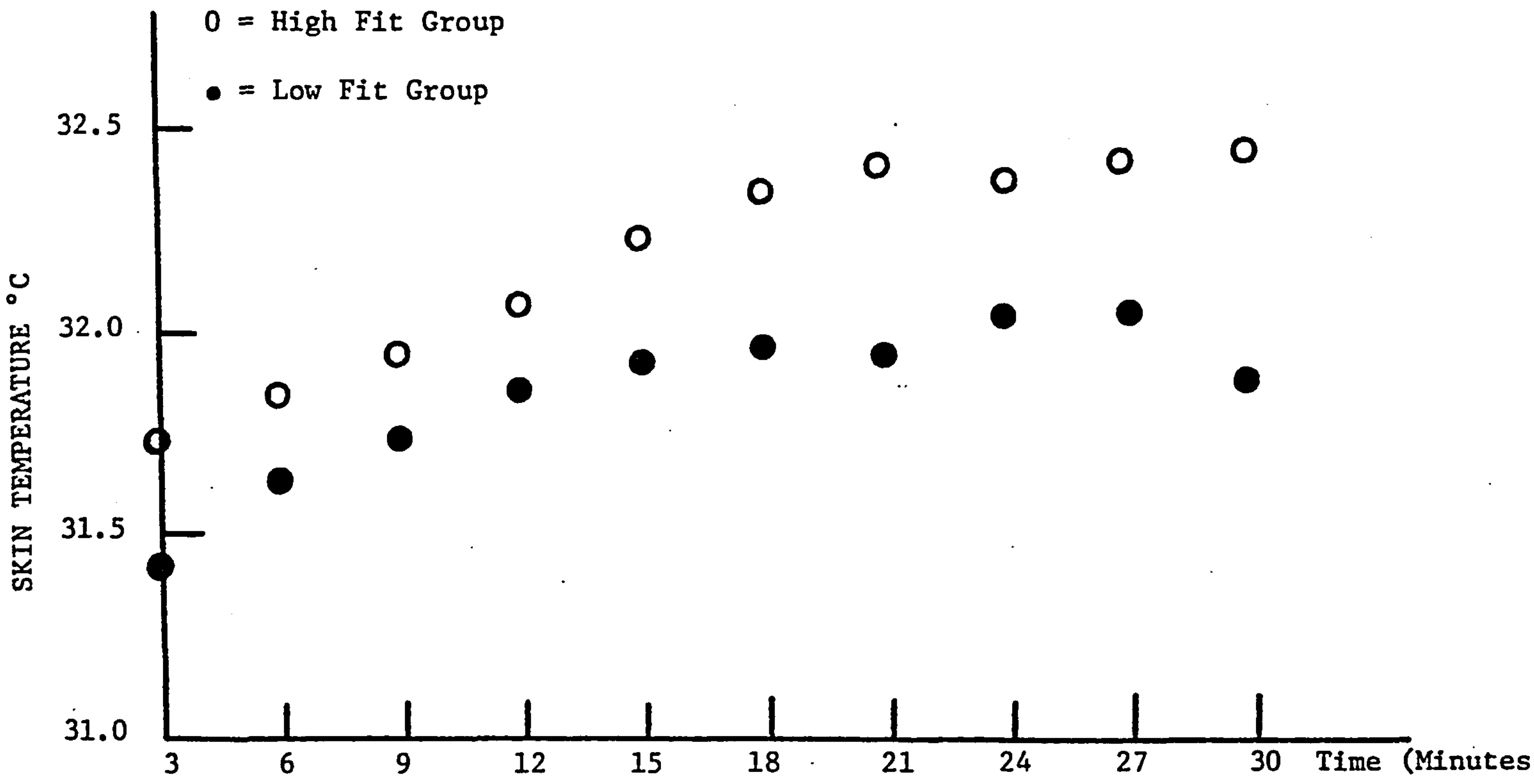

Figure 6

Mean Skin Temperature of High and Low Fitness Groups
During Recovery from Exercise

Table 6

Honestly Significant Differences Resulting from Tukey Test Comparing Skin Temperature Changes by Body Location During Recovery From Exercise

		Gastrocnemius	Bicep	Rectus Femoris	Heart	Thumb	Palm
Location	T_s °C	31.59	31.66	31.70	31.79	31.91	32.56
Head	32.85	1.26[a]	1.19[a]	1.15[a]	1.06[a]	.94[a]	.29[a]
Palm	32.56	.97[a]	.90[a]	.86[a]	.77[a]	.65[a]	
Thumb	31.91	.32[a]	.25[a]	.21[a]	.12		
Heart	31.79	.20[a]	.13	.09			
Rectus Femoris	31.70	.11	.04				
Bicep	31.66	.07					
Gastrocnemius	31.59						

[a]P at .01 = .18

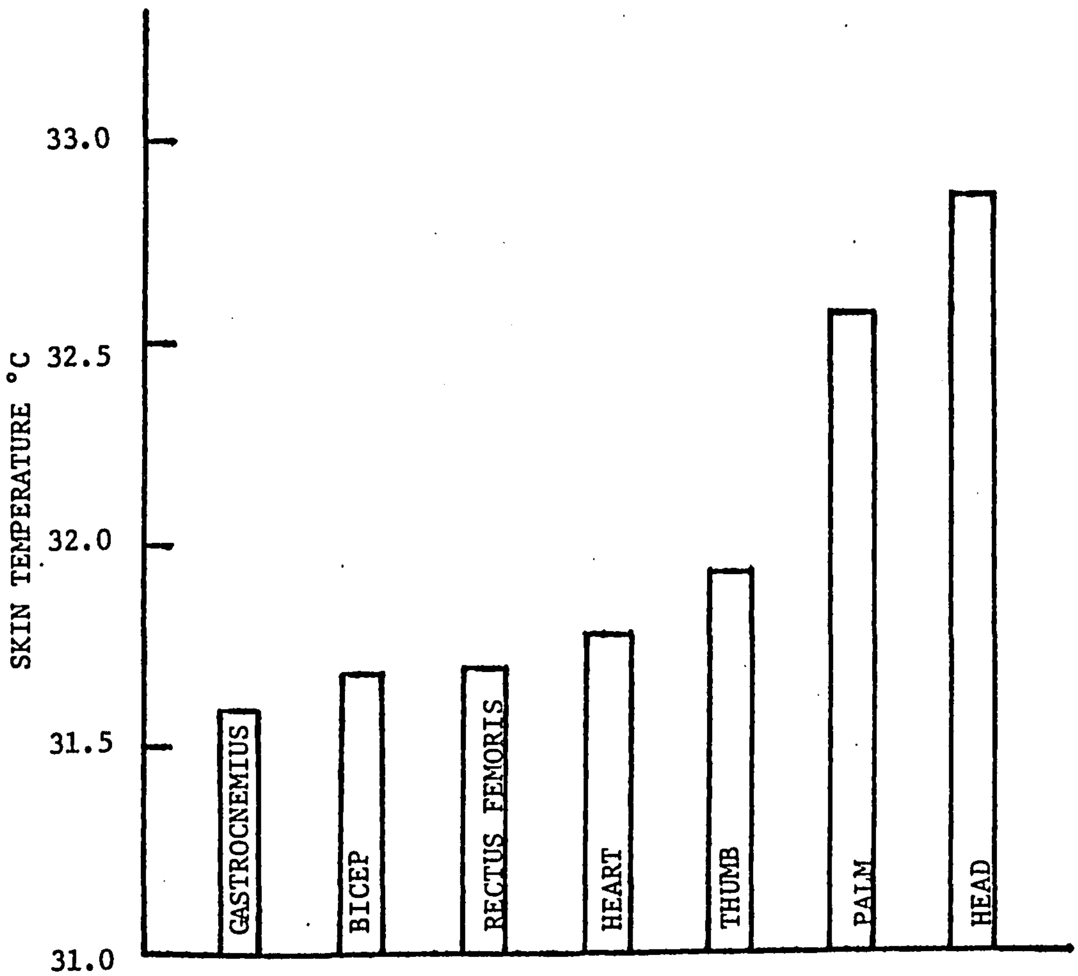

Figure 7

Mean Skin Temperature of Various Body Locations Experienced by Both Fitness Groups During Recovery from Exercise

Table 7

Honestly Significant Differences Resulting from Tukey Test Comparing Changes in Skin Temperature by Fitness Groups and Body Locations During Recovery From Exercise

Location	T_s^* °C	Heart -.05	Head .19	Bicep .21	Rectus Femoris .28	Gastroc-nemius .54	Palm .59
Thumb	.68	.73[b]	.49[b]	.47[b]	.40[b]	.14	.09
Palm	.59	.64[b]	.40[b]	.38[b]	.31[b]	.05	
Gastroc-nemius	.54	.59[b]	.35[b]	.33[b]	.26[b]		
Rectus Femoris	.28	.33[b]	.09	.07			
Bicep	.21	.26[b]	.02				
Head	.19	.24[a]					
Heart	-.05						

* Indicates differences in skin temperature between fitness groups in favor of the high group.

[a]P at .05 = .22

[b]P at .01 = .26

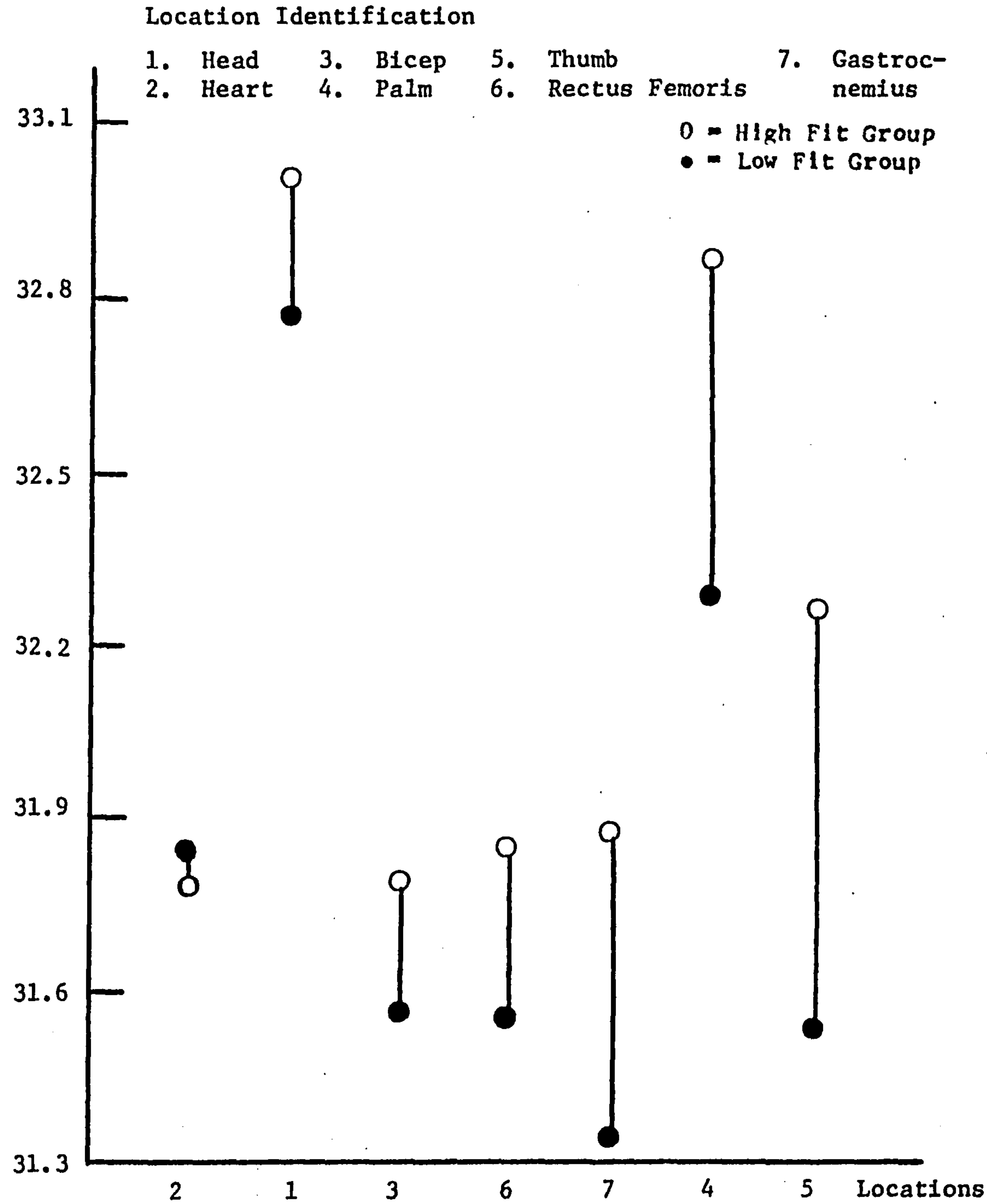

Figure 8

Mean Skin Temperature Readings of Various Parts of the Body for High and Low Fitness Groups during Recovery from Exercise heart location was significantly less than the remaining six body locations. The ranges in skin temperature of the rectus femoris, biceps, and head locations were found to be significantly less than the divergences noted for the gastrocnemius, palm and thumb locations.

Regression Analysis of Skin Temperature Relationships Among Fitness Groups and Total Subject Population by Location During Exercise and Through Recovery

The final analysis of data focused upon the relationships that existed between the variables of skin temperature, heart rate, and time. Tests for linear, quadratic, and cubic characteristics of the curve representing the relationships between these variables were undertaken. Tables 8 and 9 provide a guide to those body locations where a significant relationship between the variables was found.

Regression Analysis of Skin Temperature Relationships in Fitness Groups and Total Subject Population During Exercise

Table 8 presents the probability levels of the skin temperature and heart rate relationship of high and low fitness groups and for all sixty subjects combined for each of the seven body locations studied. Skin temperature was the dependent variable. Appendix C provides information for the relationships recorded in Table 8.

The tests provided the following results:

1. The high fitness group showed an inverse linear relationship between decreasing skin temperature and rising heart rate at the bicep and rectus femoris locations. These were significant at the .05 level of probability.

Table 8

Regression Probability Levels of Skin Temperature Relationships with Heart Rate in Fitness Groups and Total Population of Sixty Subjects During Exercise with Skin Temperature as a Dependent Variable

BODY LOCATIONS

		Head	Heart	Bicep	Palm	Thumb	Rectus Femoris	Gastrocnemius
High Fit	L	None	None	.05	None	None	.05	None
	Q	None	None	None	None	None	None	None
	C	None	None	None	None	None	None	None
Low Fit	L	.05	.05	.05	.01	.05	.05	.01
	Q	None	None	None	None	None	None	None
	C	None	None	None	None	None	None	None
All Sixty	L	.01	.01	.01	.01	.01	.01	.01
	Q	None	.05	None	.01	.05	None	None
	C	None	None	None	None	None	None	None

.05 and .01 indicate levels of probability

L = Linear

Q = Quadratic

C = Cubic

2. The analysis covering the low fitness group showed that all seven body locations had a significantly inverse linear relationship between decreasing skin temperature and rising heart rate.

When skin temperature of the total subject pupulation was compared with exercise heart rate, the seven body locations had an inverse linear relationship significant at the .01 level of probability where skin temperature decreased while the heart rate increased.

Regression Analysis of Skin Temperature Relationships in Fitness Groups and All Sixty Subjects through Thirty Minutes of Recovery

Table 9 presents the regression comparisons of skin temperature, heart rate, and time with the former being the dependent variable. Data supporting the areas of significance in Table 9 may be found in Appendix D.

In regard to skin temperature patterns of the high fitness group during recovery: the increasing skin temperature and decreasing heart rate relationship was significantly linear at the .01 level of probability for all seven body locations; cubic characteristics were noted in the heart rate and skin temperature relationship at the heart, palm, and gastrocnemius locations; and the recovery time and skin temperature relationships was limited to a linear relationship at the heart location with the other six sites showing no significant trend.

While the high fitness group showed an inverse linear relationship between the decreasing heart rate and rising skin temperature, exclusive of the heart location, the low fit group generally showed a quadratic trend between the same variables and a linear relationship between the time and skin temperature analysis. Specifically,

Table 9

Regression Probability Levels of Skin Temperature Relationships with Heart Rate and Time in Fitness Groups and Total Population of Sixty Subjects During Recovery from Exercise with Skin Temperature as a Dependent Variable

		BODY LOCATIONS													
		Head		Heart		Bicep		Palm		Thumb		Rectus Femoris		Gastroc-Nemius	
		HR	TI	HR	TI	HR	TI	HR	TI	HR	TI	HR	TI	HR	TI
High Fit	L	.01	.01	.01	None	.01	None	.01	None	.01	None	.01	None	.01	None
	Q	None	None	None	None	None	None	None	None	None	None	None	None	None	None
	C	None	None	.05	None	None	None	.01	None	.01	None	.01	None	.01	None
Low Fit	L	None	.01	None	.01	None	.01	None	.01	None	None	None	.01	.05	.01
	Q	None	.01	.05	None	.05	None	.05	None	None	None	.01	None	.01	None
	C	None	None	None	None	None	None	None	None	None	None	None	None	None	None
All Sixty	L	.01	.01	.01	.01	.05	.01	.05	.01	.05	None	.01	.01	.01	None
	Q	None	None	.01	None	None	None	None	None	None	None	None	None	.05	.05
	C	None	None	.01	None	.05	None	.01	None	.01	None	.01	None	.01	None

.05 and .01 indicate levels of probability L = Linear Q = Quadratic HR = Heart Rate C = Cubic TI = Time a study of the low fitness group's recovery period showed:

1. A quadratic relationship existed between decreasing heart rate and increasing skin temperature at the heart, bicep, palm, rectus femoris, and gastrocnemius locations.

2. Lowering heart rate and rising skin temperature at the gastrocnemius location had a significant inverse linear relationship.

3. No significant relationships were found to exist between heart rate and skin temperature at the head and thumb locations.

4. The thumb was the only location not to show a relationship between skin temperature and time. The remaining six locations were significantly linear at the .01 level of probability with the head location also showing a significant quadratic curve at the .01 level.

When the data for the sixty subjects were compared, the following results were found:

1. Within the decreasing heart rate and rising skin temperature relationship: (a) all seven locations had a significantly inverse linear relationship. The head, heart, bicep, rectus femoris, and gastrocnemius were significant at the .01 level of probability; the palm and thumb at the .05 level; (b) two locations, the heart and gastrocnemius also showed deviations from linearity of a quadratic leveling at the .01 and .05 levels of probability respectively.

2. While comparing the rising skin temperature and time relationship: (a) linear relationships existed at the .01 level of probability at the head, heart, bicep, palm, and rectus femoris location. (b) A quadratic deviation from linearity was found to be significant at the .05 level at the gastrocnemius site. (c) No significant relationships existed at the thumb location.

CHAPTER 5

SUMMARY, FINDINGS, DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was conducted to determine whether variances in physical fitness as defined in this study would cause differences in skin temperature patterns during exercise and through a thirty minute recovery period. The primary purpose was to determine if the skin temperature patterns of high and low fitness groups would differ significantly during an exercise load with four dynalevels and through recovery from exercise. A secondary purpose was to determine whether a specific body location could be found which would indicate that radiometer could be used to measure physical fitness.

Sixty male subjects were randomly selected to study the relationships between heart rate and skin temperature induced by exercise dynalevels performed on a motor driven treadmill. A high and low fitness group was separated for additional study to determine whether differences and/or relationships were present due to the factor of fitness. The subjects were classified by the amount of time necessary for the heart rate of a subject to attain 180 beats per minute. Seven body locations were studied: forehead, a point immediately inferior to the sternum, belly of the left bicep, center of the left palm, tip of the left thumb, belly of the left rectus femoris, and belly of the left gastrocnemius.

Skin temperature and heart rate were obtained by using a Barnes radiometer and a cardio-tach while subjects were tested in a 72-76°F environment. Resting skin temperature and heart rate measurements were taken after a fifteen minute rest period and were continued throughout the exercise phase as heart rates attained 120, 140, 160, and 180 beats per minute. Monitoring for skin temperature and heart rate were continued throughout the thirty minute recovery period at three minute intervals.

A split-plot factorial analysis of variance was used to determine whether differences existed in skin temperature changes at seven body locations among high and low fitness groups due to the effects of exercise stress at various dynalevels. An additional split-plot factorial analysis of variance was used to find out what effects recovery time had upon skin temperature changes experienced by high and low fitness groups. Curvilinear regression equations were employed to study the skin temperature and heart rate relationship for fitness groups and the total subject population at the seven body sites during exercise. Curvilinear regression equations were used to study the relationships between skin temperature and time and skin temperature and heart rate for both groups and the total subject population at all seven body locations through thirty minutes of recovery.

Findings

The findings in this study were as follows:

1. Both fitness groups experienced a significant linear decrease in skin temperature from the resting level as heart rate increased.

2. Both groups showed a significant drop in skin temperature at onset of exercise.
3. A significant interaction was found between skin temperature of high and low fitness groups during exercise; when heart rate approached the upper limits skin temperature of the high fitness group demonstrated a return to normal, the low fitness group experienced a continued drop in temperature.
4. The head location experienced significantly higher temperatures during exercise than five other body locations with the exception of the heart location.
5. The thumb location was significantly lower in skin temperature during exercise than the other six body locations.
6. The seven body locations did not react uniformly in skin temperature patterns as a result of increased exercise stress.
7. Both fitness groups experienced a significant linear increase in skin temperature during recovery from exercise.
8. A significant leveling was experienced in the skin temperature of the fitness groups during the later phases of recovery from exercise.
9. A significant interaction between the high and low fitness groups and skin temperature recovery time intervals was found; where the high fitness group continued a linear trend of increasing magnitude, the low fitness group began to level off.
10. The head and palm locations were high emitters of body

temperature during the thirty minute recovery period.

11. Skin temperature changes during a thirty minute recovery period did not change uniformly in regard to body location for either fitness group.
12. Highly fit exercising subjects displayed a significant inverse linear relationship between decreasing skin temperature and rising heart rate at the bicep and rectus femoris locations.
13. Low fit exercising subjects displayed a significant inverse linear relationship between decreasing skin temperature and increasing heart rate at all seven body locations.
14. The total subject population experienced a significant inverse linear relationship between decreasing skin temperature and increasing heart rate during exercise for all seven body locations; significant deviations from linearity were found for the heart, palm, and thumb locations.
15. The high fitness group experienced a significant inverse linear relationship between rising skin temperature and decreasing heart rate during recovery from exercise for all seven body locations.
16. The low fitness group experienced a significant linear increase in skin temperature during recovery from exercise at all body locations except the thumb.
17. A significant linear pattern was found with the total subject population where skin temperature increased through

recovery time at the head, heart, bicep, palm, and rectus femoris locations.

Discussion

The findings in this study were in partial agreement with the results of studies conducted by Saltin et al.[1] and Loiselle.[2] Saltin found that skin temperature gradually dropped approximately 2°C and remained rather constant during the first ten minutes of exercise. Fitness groups of the present study experienced a gradual drop from the resting rate through a heart rate of 180 beats per minute, but did not display as large a variation in skin temperature. A change of .69°C was noted in this study.

The findings of Loiselle, who stated that exercising skin temperature overlying an active muscle was lower than the average temperature of six other nonworking body areas, were not in total agreement with the findings of the present study. Although in the present study the head and heart were higher in skin temperature during exercise than the working muscles, (rectus femoris, gastrocnemius, and bicep) the palm and thumb showed changes lower than the working muscle groups.

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[1]B. Saltin and others, "Muscle Temperature During Submaximal Exercise in Man," Journal of Applied Physiology, XXV (December, 1968), 679-88.

[2]Denis Loiselle, "The Effects of Varied Thermal Environments on Selected Physiological Variables," Microcarded Master's thesis, University of Alberta, Edmonton, 1966, pp. 14-54.

This investigator's findings did not support the conclusion of Lynch *et al.*[3] that exercise had no major consistent effect on blood flow in overlying skin during exercise, since a significant difference in the drop in skin temperature was found from the resting rate through 180 beats per minute.

The finding by O'Connell[4] that skin temperature increased significantly during recovery from exercise stress was also observed in the present study.

A brief summary of the present study shows that skin temperature dropped from the resting rate of 31.62°C to 30.93°C at 180 beats per minute and began a return to normal at the first recovery monitoring at three minutes to 31.57°C. From this point skin temperature continued to rise above the resting level to 32.16°C at the thirty minute monitoring period.

Although a return to the normal resting skin temperature level was not experienced in this study, the quadratic deviation from linearity which occurred during the last ten minutes of monitoring indicated that such a trend could occur within a short period of time.

The primary problem of the study was to determine whether high and low fitness individuals would differ significantly in skin

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[3] P. R. Lynch and others, "Results of Studies Using Two Radiological Methods in Investigating the Circulation of Exercising Human Arms," *Journal of Physiology*, CCXIII (March, 1971), 41P-42P.

[4] Eugene R. O'Connell, "The Effect of Local Isometric Muscular Activity on Local Skin Temperature," *Journal for the Association for Physical and Mental Rehabilitation*, XIV (May-June, 1960), 74-75.

temperature patterns due to exercise stress and through a thirty minute recovery period. Although a drop in skin temperature was expected during the increased exercise stress, the fact that both fitness groups displayed a linear decreasing trend was not expected. The significant interaction which resulted between the high and low fitness groups reaction to exercise stress answered the primary question. The physical fitness level of a subject caused variations in the skin temperature patterns when subjected to exercise stress of increased proportions. The difference in reaction to exercise stress occurred as the heart rate approached the dynalevel of 180 beats per minute. At this point the skin temperature of the high fitness group began a return to the resting level, whereas the low fitness group continued its decreasing linear trend. A possible explanation for this divergence between the two fitness groups may lie in the extended time required for the high fitness group to attain 180 beats per minute. Such stress possibly necessitated the dissipation of heat through vasodilation of the subcutaneous tissue even though a shunting of this blood flow is commonly assumed to take place to provide additional blood flow to the underlying working muscles. Vasodilation in the subcutaneous tissue area could be a result of the impending maximal stress experienced by the high fitness group since there was uniformity between both groups in skin temperature patterns even up to the 160 beat per minute level.

The recovery patterns for both fitness groups demonstrated a linear trend of increasing skin temperature with a quadratic leveling during the last ten minutes of exercise. The interaction between the fitness groups suggested that the more fit individual experienced higher skin temperature values than the low fit individual. Uniformity of increasing skin temperature between both groups existed for the first fifteen minutes. After this point the low fitness group began experiencing a leveling followed by a drop in temperature.

The high fitness group continued to experience an increase in skin temperature throughout the thirty minutes. This divergence from the low fitness group could possibly be explained by the greater amount of time the high fitness group had to exercise to reach the dynalevel of 180 beats per minute. Although lower fit subjects recovered more quickly from the work load, it may be due to the fact that they had exercised for a shorter period of time.

An additional possibility for the difference between the temperature recovery patterns of the groups may lie in physiological temperature adjustments, an area which Astrand and Rodahl[5] indicated was largely unknown. Since the higher fitness group was accustomed to exercise in greater amounts at the equivalent heart rate, they may have developed more efficient heat releasing mechanisms through vasodilation than the low fitness group. This adjustment would seem imperative if the core temperature is to be maintained within the 4°C range as reported by Astrand and Rodahl.[6]

The interaction between the fitness groups and changes in skin temperature by body location during recovery from exercise showed that a lack of uniformity existed among several sites. The main working muscle groups monitored, the rectus femoris and gastrocnemius,

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[5]Per-Olof Astrand and Kaare Rodahl, <u>Textbook of Work Physiology</u>, (New York: McGraw-Hill Book Company, 1970), p. 509.

[6]<u>Ibid</u>., p. 491.

showed divergences of .28°C and .54°C, respectively. Temperatures for the high fitness group were high for both locations. Again, the difference in the temperature recovery patterns of these working muscles could be related to the extended time it took for the high fitness group to complete the exercise task.

The heart site was the only area where the unfit group experienced a higher temperature than the fit group. This variation, .05°C, was so small that any possible significance which could be assumed was that there was no difference. The heart was the only location to show such agreement. The heart area did not experience any changes through recovery regardless of fitness whereas the extremities did show such a divergence. It would seem logical to assume that the time taken for the fit group to reach the final heart rate dynalevel did not affect the reaction of the heart area in any way differently than the unfit group. There was little difference in the heat producing heart functions of both groups as a result of exercise. Differences lie in the vascular extremities in relation to skin temperature. Also, it must be realized that the only muscle still in a working state during recovery was the heart. The cause for the uniformity between groups through recovery may be related to the continued activity of the heart during the resting period.

The secondary purpose of the study was to determine if a specific body location could be found that possessed the necessary qualities that may establish radiometry as a method for determining an individual's level of physical fitness.

A review of the regression analyses to find such a location was conducted. During the exercise phase of the study the bicep brachii and rectus femoris locations possessed linear qualities for the high and low fitness groups and the sixty subject sample. However, little divergence between the two fitness groups was noted in the plots, (see Appendixes G and H) and the two sites were not considered further.

The recovery from exercise results indicated the head location was the only site demonstrating a linear relationship between skin temperature and time among all three groups. The fitness group displayed no distinguishing qualities in skin temperature change through recovery time that could be utilized to develop a testing criterion. See Appendix I.

After reviewing the data collected the palm site provided the best possibility for further study. Appendixes J and K present the skin temperature graphic plots of the palm location during exercise and through recovery. There appears to be enough differences in skin temperature between the fitness groups beginning with the dynalevel of 140 beats per minute, .35°C, and increasing to the final exercise monitoring at 180 beats per minute, .83°C, to warrant further study. The use of this site may allow the development of a physical fitness test that would monitor skin temperature immediately after the heart rate attained 140, 160, or 180 beats per minute and through an index provide the fitness level of the individual. In addition to the above monitoring periods, there seems to be enough difference in skin temperature between the two fitness groups at three minutes into recovery, .65°C, to merit further investigation.

Conclusions

Within the limitations of this study the following conclusions were made:

1. Low fit individuals experience lower skin temperature than highly fit individuals as exercise increases to maximal levels.

2. Highly fit individuals experience higher skin temperatures during recovery from exercise than low fit individuals.

3. There is evidence that the fitness level of an individual may be determined by measuring skin temperature at the center of the palm.

Recommendations

1. A longitudinal study should be conducted to determine what effects age would have upon skin temperature patterns as a result of exercise stress.

2. A study should be conducted to determine whether resting skin temperature monitoring of the palm would correlate highly with the results of an established test of physical fitness.

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APPENDIXES

APPENDIX A

SKIN TEMPERATURE AND HEART RATE DATA SHEET

Date/Time ___________

Name _________________ Age ____ Ht. ________ Wt. ________

Room Temp ______ Superior ______ Inferior ______

PRE MEASURES

T/PLS	COU	HEAD	RIB	BICE	PALM	THUM	RECT	GAST	TIME
0	____	____	____	____	____	____	____	____	XXXX

EXERCISE DATA

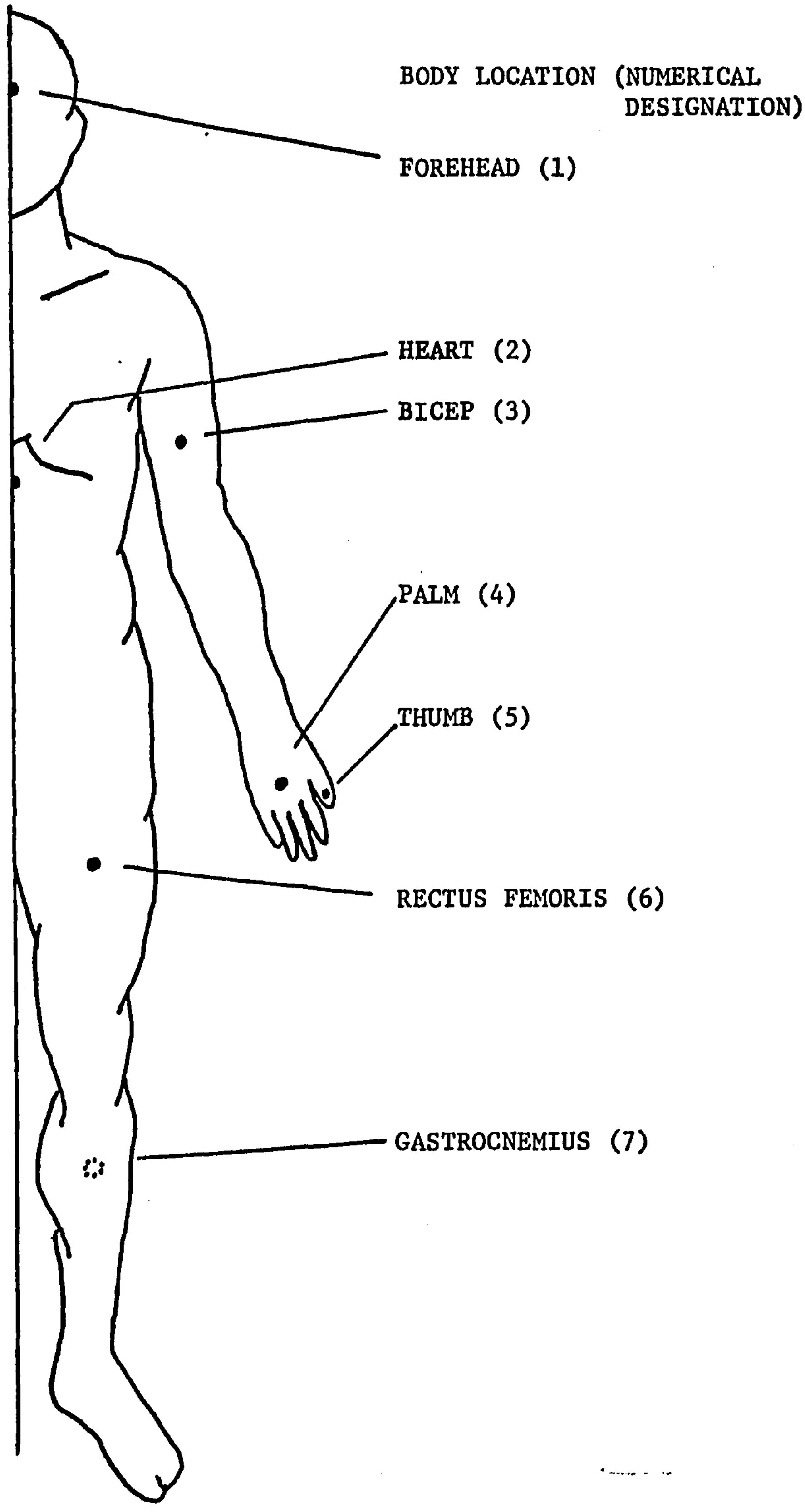
	120	____	____	____	____	____	____	____	____
	140	____	____	____	____	____	____	____	____
	160	____	____	____	____	____	____	____	____
	180	____	____	____	____	____	____	____	____

RECOVERY DATA

3	____	____	____	____	____	____	____	____	____
6	____	____	____	____	____	____	____	____	____
9	____	____	____	____	____	____	____	____	____
12	____	____	____	____	____	____	____	____	____
15	____	____	____	____	____	____	____	____	____
18	____	____	____	____	____	____	____	____	____
21	____	____	____	____	____	____	____	____	____
24	____	____	____	____	____	____	____	____	____
27	____	____	____	____	____	____	____	____	____
30	____	____	____	____	____	____	____	____	____

APPENDIX B

PICTORIAL DESCRIPTION OF SEVEN ANATOMICAL LOCATIONS STUDIED



APPENDIX C

ANALYSIS OF VARIANCE TABLES AND INTERCEPT PLOT DATA USED IN REGRESSION ANALYSES OF SKIN TEMPERATURE RELATIONSHIPS IN FITNESS GROUPS AND TOTAL SUBJECT POPULATION WHILE ATTAINING FOUR EXERCISE DYNALEVELS

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Location 1, Group 2, Linear						
Regression		1	141.10	141.10	4.22	.04
Error		73	2441.56	33.45		
Intercept	33.01					
Heart Rate	-0.04					
Location 2, Group 2, Linear						
Regression		1	180.28	180.28	4.19	.04
Error		73	3140.87	43.03		
Intercept	32.31					
Heart Rate	-0.05					
Location 3, Group 1, Linear						
Regression		1	790.71	790.71	4.29	.04
Error		73	13441.20	184.13		
Intercept	32.37					
Heart Rate	-0.09					
Location 3, Group 2, Linear						
Regression		1	406.14	406.14	5.22	.03
Error		73	5672.34	77.70		
Intercept	32.01					
Heart Rate	-0.07					

APPENDIX C (Continued)

Source of Variation	B Values	df	Sum of Squares	M^2	F	P
Location 4, Group 2, Linear						
Regression		1	1623.16	1623.16	14.42	.01
Error		73	8219.72	112.60		
Intercept	32.60					
Heart Rate	-0.14					
Location 5, Group 2, Linear						
Regression		1	1511.53	1511.53	5.36	.02
Error		73	20588.66	282.04		
Intercept	31.68					
Heart Rate	-0.13					
Location 6, Group 1, Linear						
Regression		1	1054.82	1054.82	5.28	.02
Error		73	14577.37	199.69		
Intercept	32.51					
Heart Rate	-0.10					
Location 6, Group 2, Linear						
Regression		1	270.14	270.14	4.76	.03
Error		73	4142.53	56.75		
Intercept	31.85					
Heart Rate	-0.06					
Location 7, Group 2, Linear						
Regression		1	402.24	402.24	8.85	.01
Error		73	3317.14	45.44		
Intercept	31.83					
Heart Rate	-0.07					

APPENDIX C (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
REGRESSION RELATED TO THE TOTAL SUBJECT POPULATION						
Location 1, Linear						
Regression		1	1136.56	1136.56	12.02	.01
Error		298	28169.19	94.53		
Intercept	33.21					
Heart Rate	-0.05					
Location 2, Quadratic						
Regression		2	2642.96	1321.48	12.87	.01
Error		298	30493.04	102.67		
			(Partial SS)			
Heart Rate		1	161.40		1.57	.21
Heart $Rate^2$		1	387.90		3.78	.05
Intercept	31.47					
Heart Rate	0.14					
Heart $Rate^2$	-0.00					
Location 2, Linear						
Regression		1	2255.06	2255.06	21.76	.01
Error		298	30880.94	103.63		
Intercept	32.74					
Heart Rate	-0.08					
Location 3, Linear						
Regression		1	2468.72	2468.72	18.17	.01
Error		298	40493.72	135.88		
Intercept	32.32					
Heart Rate	-0.08					
Location 4, Quadratic						
Regression		2	5183.38	2591.69	12.01	.01
Error		297	64080.29	215.76		
			(Partial SS)			
Heart Rate		1	2091.31		9.69	.01
Heart $Rate^2$		1	1392.16		6.45	.01

APPENDIX C (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Intercept	34.65					
Heart Rate	-0.52					
Heart Rate^2	0.00					
<u>Location 4, Linear</u>						
Regression		1	3791.21	3791.21	17.26	.01
Error		298	65472.45	219.71		
Intercept	32.25					
Heart Rate	-0.10					
<u>Location 5, Quadratic</u>						
Regression		2	4515.48	2257.74	5.07	.01
Error		297	132101.07	444.78		
			(Partial SS)			
Heart Rate		1	2314.08		5.20	.02
Heart Rate^2		1	1673.08		3.76	.05
Intercept	33.47					
Heart Rate	-0.54					
Heart Rate^2	0.00					
<u>Location 5, Linear</u>						
Regression		1	2842.40	2842.40	6.33	.01
Error		298	133774.14	448.91		
Intercept	30.84					
Heart Rate	-0.09					
<u>Location 6, Linear</u>						
Regression		1	2819.18	2819.18	22.98	.01
Error		298	36551.07	122.65		
Intercept	32.35					
Heart Rate	-0.09					

APPENDIX C (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Location 7, Linear						
Regression		1	1009.65	1009.64	7.22	.01
Error		297	41549.26	139.90		
Intercept	31.77					
Heart Rate	-0.05					

APPENDIX D

ANALYSIS OF VARIANCE TABLES AND INTERCEPT PLOT DATA USED IN REGRESSION ANALYSES OF SKIN TEMPERATURE RELATIONSHIPS IN FITNESS GROUPS AND TOTAL SUBJECT POPULATION WHILE RECOVERING FROM EXERCISE

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Location 1, Group 1, Linear Heart Rate						
Regression		2	1898.97	949.49	9.11	.01
Error		147	15320.42	104.22		
			(Partial SS)			
Heart Rate		1	1114.16		10.69	.01
Intercept	34.53					
Heart Rate	-0.21					
Location 2, Group 1, Cubic Heart Rate						
Regression		6	4329.41	721.57	5.05	.01
Error		143	20448.25	142.99		
			(Partial SS)			
Heart $Rate^3$		1	716.37		5.01	.01
Intercept	43.25					
Heart $Rate^3$	0.00					
Location 2, Group 1, Linear Heart Rate, Time						
Regression		2	3334.15	1667.08	11.43	.01
Error		147	21443.51	145.87		
			(Partial SS)			
Heart Rate		1	1154.11		7.91	.01
Time		1	1062.80		7.29	.01
Intercept	33.09					
Heart Rate	-0.21					
Time	0.33					
Location 3, Group 1, Linear Heart Rate						
Regression		2	3672.35	1836.18	13.60	.01
Error		147	19844.98	134.99		
			(Partial SS)			
Heart Rate		1	2599.95		19.26	.01

APPENDIX D (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Intercept	34.34					
Heart Rate	-0.32					
Location 4, Group 1, Cubic Heart Rate						
Regression		6	4784.97	797.50	5.53	.01
Error		143	20637.71	144.31		
			(Partial SS)			
Heart Rate^3		1	2250.46		15.59	.01
Intercept	51.31					
Heart Rate^3	0.00					
Location 4, Group 1, Linear Heart Rate						
Regression		2	2241.72	1120.86	7.11	.01
Error		147	23180.98	157.69		
			(Partial SS)			
Heart Rate		1	1246.08		7.90	.01
Intercept	34.50					
Heart Rate	-0.22					
Location 5, Group 1, Cubic Heart Rate						
Regression		6	9350.97	1558.49	5.20	.01
Error		143	42836.29	299.55		
			(Partial SS)			
Heart Rate^3		1	5290.96		17.66	.01
Intercept	61.98					
Heart Rate^3	0.00					
Location 5, Group 1, Linear Heart Rate						
Regression		2	3418.82	1709.41	5.15	.01
Error		147	48768.44	331.76		
			(Partial SS)			
Heart Rate		1	3065.22		9.24	.01
Intercept	35.30					
Heart Rate	-0.35					

APPENDIX D (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Location 6, Group 1, Cubic Heart Rate						
Regression		6	3186.37	531.06	3.36	.01
Error		143	22588.19	157.96		
			(Partial SS)			
Heart $Rate^3$		1	991.59		6.28	.01
Intercept	45.20					
Heart $Rate^3$	0.00					
Location 6, Group 1, Linear Heart Rate						
Regression		2	2113.91	1056.96	6.57	.01
Error		147	23660.65	160.96		
			(Partial SS)			
Heart Rate		1	1555.88		9.67	.01
Intercept	33.86					
Heart Rate	-0.25					
Location 7, Group 1, Cubic Heart Rate						
Regression		6	3766.58	627.76	4.02	.01
Error		143	22324.52	156.12		
			(Partial SS)			
Heart $Rate^3$		1	1039.53		6.65	.01
Intercept	45.42					
Heart $Rate^3$	0.00					
Location 7, Group 1, Linear Heart Rate						
Regression		2	2535.51	1267.76	7.91	.01
Error		147	23555.57	160.24		
			(Partial SS)			
Heart Rate		1	2182.45		13.62	.01
Intercept	34.40					
Heart Rate	-0.29					

APPENDIX D (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Location 1, Group 2, Quadratic Time						
Regression		4	711.67	177.92	4.99	.01
Error		145	5172.87	35.67		
			(Partial SS)			
$Time^2$		1	313.26		8.78	.01
Intercept	32.43					
$Time^2$	-0.02					
Location 1, Group 2, Linear Time						
Regression		2	398.05	199.02	5.33	.01
Error		147	5486.49	37.32		
			(Partial SS)			
Time		1	387.89		10.39	.01
Intercept	31.82					
Time	0.19					
Location 2, Group 2, Quadratic Heart Rate						
Regression		4	917.59	229.40	5.05	.01
Error		145	6585.00	45.41		
			(Partial SS)			
Heart $Rate^2$		1	244.99		5.39	.05
Intercept	35.48					
Heart $Rate^2$	0.01					
Location 2, Group 2, Linear Time						
Regression		2	605.00	302.50	6.45	.01
Error		147	6897.59	46.92		
			(Partial SS)			
Time		1	593.16		12.64	.01
Intercept	30.70					
Time	0.24					

APPENDIX D (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Location 3, Group 2, Quadratic Heart Rate						
Regression		4	653.87	163.47	3.27	.01
Error		145	7240.13	49.93		
			(Partial SS)			
Heart $Rate^2$		1	271.66		5.44	.05
Intercept	25.07					
Heart $Rate^2$	-0.01					
Location 3, Group 2, Linear Time						
Regression		2	350.86	175.43	3.42	.05
Error		147	7543.14	51.31		
			(Partial SS)			
Time		1	336.97		6.57	
Intercept	30.34					
Time	0.18					
Location 4, Group 2, Quadratic Heart Rate						
Regression		4	1339.30	334.82	3.84	.01
Error		145	12614.36	87.00		
			(Partial SS)			
Heart $Rate^2$		1	338.35		3.89	.05
Intercept	24.79					
Heart $Rate^2$	-0.01					
Location 4, Group 2, Linear Time						
Regression		2	595.70	297.85	3.28	.05
Error		147	13357.96	90.87		
			(Partial SS)			
Time		1	592.30		6.52	.01
Intercept	31.50					
Time	0.24					

APPENDIX D (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Location 6, Group 2, Quadratic Heart Rate						
Regression		4	1393.06	348.27	8.54	.01
Error		145	5912.28	40.77		
			(Partial SS)			
Heart Rate^2		1	396.48		9.72	.01
Intercept	23.36					
Heart Rate^2	-0.01					
Location 6, Group 2, Linear Time						
Regression		2	788.53	394.27	8.89	.01
Error		147	6516.81	44.33		
			(Partial SS)			
Time		1	781.34		17.62	.01
Intercept	30.36					
Time	.28					
Location 7, Group 2, Linear Heart Rate, Time						
Regression		2	412.61	206.31	4.61	.01
Error		147	6582.86	44.78		
			(Partial SS)			
Heart Rate		1	218.99		4.89	.05
Time		1	305.38		6.82	.01
Intercept	29.96					
Heart Rate	0.12					
Time	0.17					
Location 7, Group 2, Quadratic Heart Rate						
Regression		4	794.73	198.68	4.65	.01
Error		145	6200.75	42.76		
			(Partial SS)			
Heart Rate^2		1	260.31		6.08	.01
Intercept	24.31					
Heart Rate^2	-0.01					

APPENDIX D (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
REGRESSION RELATED TO THE TOTAL POPULATION						
Location 1, Linear Heart Rate, Time						
Regression		2	4888.59	2444.29	34.68	.01
Error		597	42073.61	70.48		
			(Partial SS)			
Heart Rate		1	1450.25		20.58	.01
Time		1	2194.98		31.15	.01
Intercept	33.68					
Heart Rate	-0.13					
Time	0.23					
Location 2, Cubic Heart Rate						
Regression		6	9944.87	1657.48	17.58	.01
Error		593	55910.97	94.28		
			(Partial SS)			
Heart Rate^3		1	966.61		10.25	.01
Intercept	45.01					
Heart Rate^3	0.00					
Location 2, Quadratic Heart Rate						
Regression		4	8836.17	2209.04	23.05	.01
Error		595	57019.67	95.83		
			(Partial SS)			
Heart Rate^2		1	646.48		6.75	.01
Intercept	35.07					
Heart Rate^2	0.00					
Location 2, Linear Heart Rate, Time						
Regression		2	8166.89	4083.44	42.26	.01
Error		597	57688.95	96.63		
			(Partial SS)			
Heart Rate		1	1653.82		17.11	.01
Time		1	4557.16		47.16	.01

APPENDIX D (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Intercept	32.48					
Heart Rate	-0.14					
Time	0.33					
<u>Location 3, Cubic Heart Rate</u>						
Regression		6	6168.61	1028.10	10.76	.01
Error		593	56671.89	95.57		
			(Partial SS)			
Heart $Rate^3$		1	549.35		5.75	.01
Intercept	40.91					
Heart $Rate^3$	0.00					
<u>Location 3, Linear Heart Rate, Time</u>						
Regression		2	5518.63	2759.32	28.74	.01
Error		597	57321.87	96.02		
			(Partial SS)			
Heart Rate		1	3074.90		32.02	.01
Time		1	1121.20		11.68	.01
Intercept	33.64					
Heart Rate	-0.19					
Time	0.16					
<u>Location 4, Cubic Heart Rate</u>						
Regression		6	7514.22	1252.37	7.80	.01
Error		593	95147.44	160.45		
			(Partial SS)			
Heart $Rate^3$		1	3939.14		24.55	.01
Intercept	52.12					
Heart $Rate^3$	0.00					
<u>Location 4, Linear Heart Rate, Time</u>						
Regression		2	3066.79	1533.40	9.19	.01
Error		597	99594.87	166.83		
			(Partial SS)			
Heart Rate		1	643.39		3.86	.05
Time		1	1683.81		10.10	.01

APPENDIX D (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Intercept	32.87					
Heart Rate	-0.09					
Time	.20					
<u>Location 5, Cubic Heart Rate</u>						
Regression		6	9741.70	1623.62	5.59	.01
Error		593	172340.96	290.63		
			(Partial SS)			
Heart Rate^3		1	7082.45		24.37	.01
Intercept	60.81					
Heart Rate^3	0.00					
<u>Location 5, Linear Heart Rate</u>						
Regression		2	2062.42	1031.21	3.42	.05
Error		597	180020.24	301.54		
			(Partial SS)			
Heart Rate		1	1594.44		5.29	.05
Intercept	32.90					
Heart Rate	-0.13					
<u>Location 6, Cubic Heart Rate</u>						
Regression		6	6447.33	1074.55	10.86	.01
Error		593	58669.54	98.94		
			(Partial SS)			
Heart Rate^3		1	1247.80		12.61	.01
Intercept	45.13					
Heart Rate^3	0.00					
<u>Location 6, Linear Heart Rate, Time</u>						
Regression		2	4640.89	2320.44	22.91	.01
Error		597	60475.98	101.30		
			(Partial SS)			
Heart Rate		1	1665.85		16.44	.01
Time		1	1780.12		17.57	.01
Intercept	32.56					
Heart Rate	-0.14					
Time	0.20					

APPENDIX D (Continued)

Source of Variance	B Values	df	Sum of Squares	M^2	F	P
Location 7, Cubic Heart Rate						
Regression		6	5238.61	873.10	8.56	.01
Error		593	60475.98	101.98		
			(Partial SS)			
Heart Rate^3		1	905.02		8.87	.01
Intercept	44.98					
Heart Rate^3	0.00					
Location 7, Quadratic Heart Rate, Time						
Regression		4	4310.68	1077.67	10.42	.01
Error		595	61557.69	103.46		
			(Partial SS)			
Heart Rate^2		1	541.13		5.23	.05
Time^2		1	402.14		3.89	.05
Intercept	35.14					
Heart Rate^2	0.00					
Time^2	-0.01					
Location 7, Linear Heart Rate						
Regression		2	3459.55	1729.78	16.55	.01
Error		597	62408.82	104.54		
			(Partial SS)			
Heart Rate		1	2500.35		23.92	.01
Intercept	32.95					
Heart Rate	-0.17					

APPENDIX E

MEAN DATA USED IN SPLIT-PLOT FACTORIAL ANALYSIS OF VARIANCE COMPARISONS OF CHANGES IN SKIN TEMPERATURE AMONG FITNESS GROUPS DURING FOUR EXERCISE DYNALEVELS

A X B X C Analysis Mean Data (N=15)

Skin Temperature By Location

Group	Heart Rate	1	2	3	4	5	6	7
1	100	32.80	31.96	31.71	31.72	30.42	31.69	31.37
	120	32.55	31.95	31.35	30.79	29.67	31.49	31.23
	140	32.29	31.68	31.33	30.72	29.39	31.29	31.13
	160	32.14	31.32	30.91	30.93	29.72	30.82	31.08
	180	32.30	31.19	30.75	31.14	30.65	30.59	30.97
2	100	32.67	31.87	31.50	31.75	30.69	31.29	31.17
	120	32.46	31.84	31.13	30.62	29.92	31.29	31.08
	140	32.47	31.72	30.94	30.37	29.62	31.17	30.97
	160	32.41	31.57	30.91	30.43	29.50	30.89	30.72
	180	32.21	31.38	30.79	30.31	29.47	30.74	30.47

B X C Analysis Mean Data (N=30)

Heart Rate	1	2	3	4	5	6	7
100	32.74	31.92	31.61	31.73	30.56	31.49	31.27
120	32.50	31.90	31.24	30.70	29.79	31.39	31.15
140	32.38	31.70	31.13	30.54	29.51	31.23	31.05
160	32.28	31.45	30.91	30.68	29.61	30.85	30.90
180	32.26	31.28	30.77	30.73	30.06	30.67	30.72

A X C Analysis Mean Data (N=75)

Group	1	2	3	4	5	6	7
1	32.42	31.62	31.21	31.06	29.97	31.17	31.16
2	32.45	31.68	31.06	30.70	29.84	31.07	30.88

APPENDIX E (Continued)

C Analysis Mean Data (N=150)

	Skin Temperature By Location						
	1	2	3	4	5	6	7
	32.43	31.65	31.13	30.88	29.91	31.12	31.02

A X B Analysis Mean Data (N=105)

Group	Heart Rate	Skin Temperature
1	100	31.67
	120	31.29
	140	31.12
	160	30.99
	180	31.08
2	100	31.56
	120	31.19
	140	31.04
	160	30.92
	180	30.77

B Analysis Mean Data (N=210)

Heart Rate	Skin Temperature
100	31.62
120	31.24
140	31.08
160	30.95
180	30.93

A Analysis Mean Data (N=525)

Group	Skin Temperature	Overall Mean (N=1050)
1	31.23	31.16
2	31.09	

APPENDIX F

MEAN DATA USED IN SPLIT-PLOT FACTORIAL ANALYSIS OF VARIANCE COMPARISONS OF CHANGES IN SKIN TEMPERATURE AMONG FITNESS GROUPS DURING RECOVERY FROM EXERCISE

A X B X C Analysis Mean Recovery Data (N=15)

Skin Temperature By Location

Group	Time	1	2	3	4	5	6	7
1	3	32.52	31.36	31.30	32.33	31.67	31.39	31.41
	6	32.74	31.14	31.36	32.44	32.00	31.66	31.69
	9	32.78	31.26	31.45	32.68	32.13	31.67	31.78
	12	32.80	31.53	31.74	32.77	32.23	31.75	31.81
	15	32.89	31.77	31.82	32.89	32.52	31.87	31.94
	18	32.98	31.91	31.89	33.03	32.62	31.91	31.99
	21	33.08	32.08	31.95	33.17	32.45	32.07	32.06
	24	33.21	32.11	32.05	33.10	32.28	31.95	32.01
	27	33.18	32.19	32.01	33.09	32.41	32.00	31.99
	30	33.29	32.31	32.09	33.09	32.15	32.09	31.94
2	3	32.32	31.46	31.29	31.68	31.28	30.97	30.96
	6	32.63	31.53	31.40	31.94	31.50	31.30	31.15
	9	32.53	31.68	31.42	32.18	31.51	31.43	31.27
	12	32.75	31.79	31.49	32.33	31.65	31.62	31.41
	15	32.87	31.85	31.61	32.37	31.83	31.63	31.37
	18	32.88	31.93	31.62	32.45	31.75	31.69	31.34
	21	33.01	31.93	31.63	32.44	31.31	31.71	31.42
	24	32.99	32.00	31.71	32.51	31.71	31.75	31.39
	27	32.93	32.01	31.74	32.47	31.85	31.71	31.41
	30	32.68	32.03	31.69	32.29	31.31	31.81	31.43

B X C Analysis Mean Recovery Data (N=30)

Time	1	2	3	4	5	6	7
3	32.42	31.41	31.30	32.00	31.47	31.18	31.19
6	32.68	31.34	31.38	32.19	31.75	31.48	31.42
9	32.65	31.47	31.44	32.43	31.82	31.55	31.53
12	32.77	31.66	31.62	32.55	31.94	31.69	31.61
15	32.88	31.81	31.71	32.63	32.18	31.75	31.66
18	32.93	31.92	31.75	32.74	32.18	31.80	31.67
21	33.04	32.01	31.79	32.80	31.88	31.89	31.74
24	33.10	32.06	31.88	32.81	31.99	31.85	31.70
27	33.05	32.10	31.88	32.78	32.13	31.85	31.70
30	32.99	32.17	31.89	32.69	31.73	31.95	31.68

APPENDIX F (Continued)

A X C Analysis Mean Recovery Data (N=150)

Skin Temperature By Location

Group	1	2	3	4	5	6	7
1	32.95	31.77	31.77	32.86	32.25	31.84	31.86
2	32.76	31.82	31.56	32.27	31.57	31.56	31.32

C Analysis Mean Recovery Data (N=300)

1	2	3	4	5	6	7
32.85	31.79	31.66	32.56	31.91	31.70	31.59

A X B Analysis Mean Recovery Data (N=105)

Group	Time	Skin Temperature	Group	Skin Temperature
1	3	31.71	2	31.42
	6	31.86		31.64
	9	31.96		31.72
	12	32.09		31.86
	15	32.24		31.94
	18	32.33		31.95
	21	32.41		31.92
	24	32.39		32.01
	27	32.41		32.02
	30	32.42		31.89

B Analysis Mean Recovery Data (N=210)

Time	Skin Temperature	Time	Skin Temperature
3	31.57	18	32.14
6	31.75	21	32.17
9	31.84	24	32.20
12	31.98	27	32.21
15	32.09	30	32.16

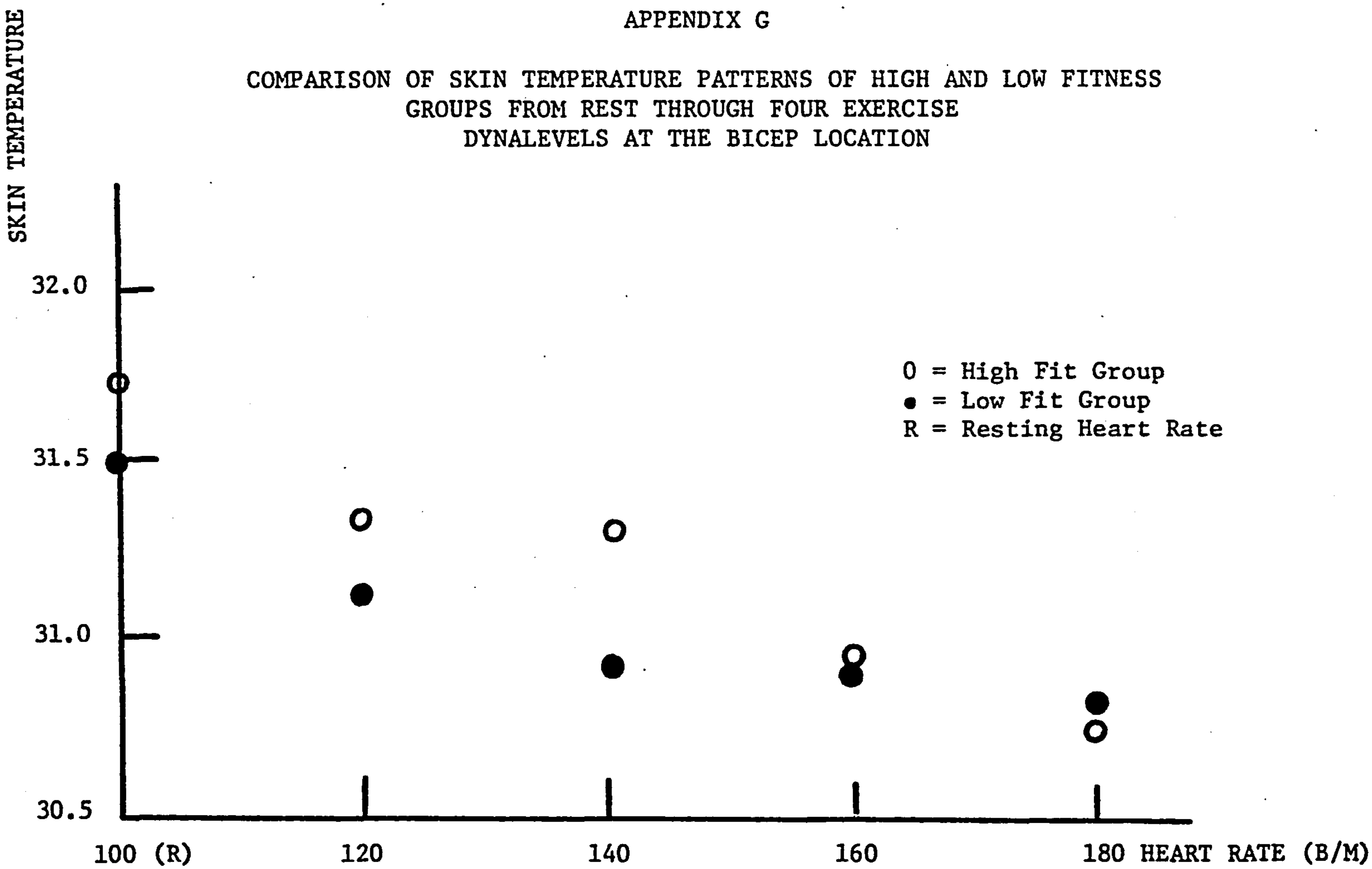
APPENDIX F (Continued)

A Analysis Mean Recovery Data (N=1050)

Group	Skin Temperature	Overall (N=2100)
1	32.18	32.01
2	31.84	

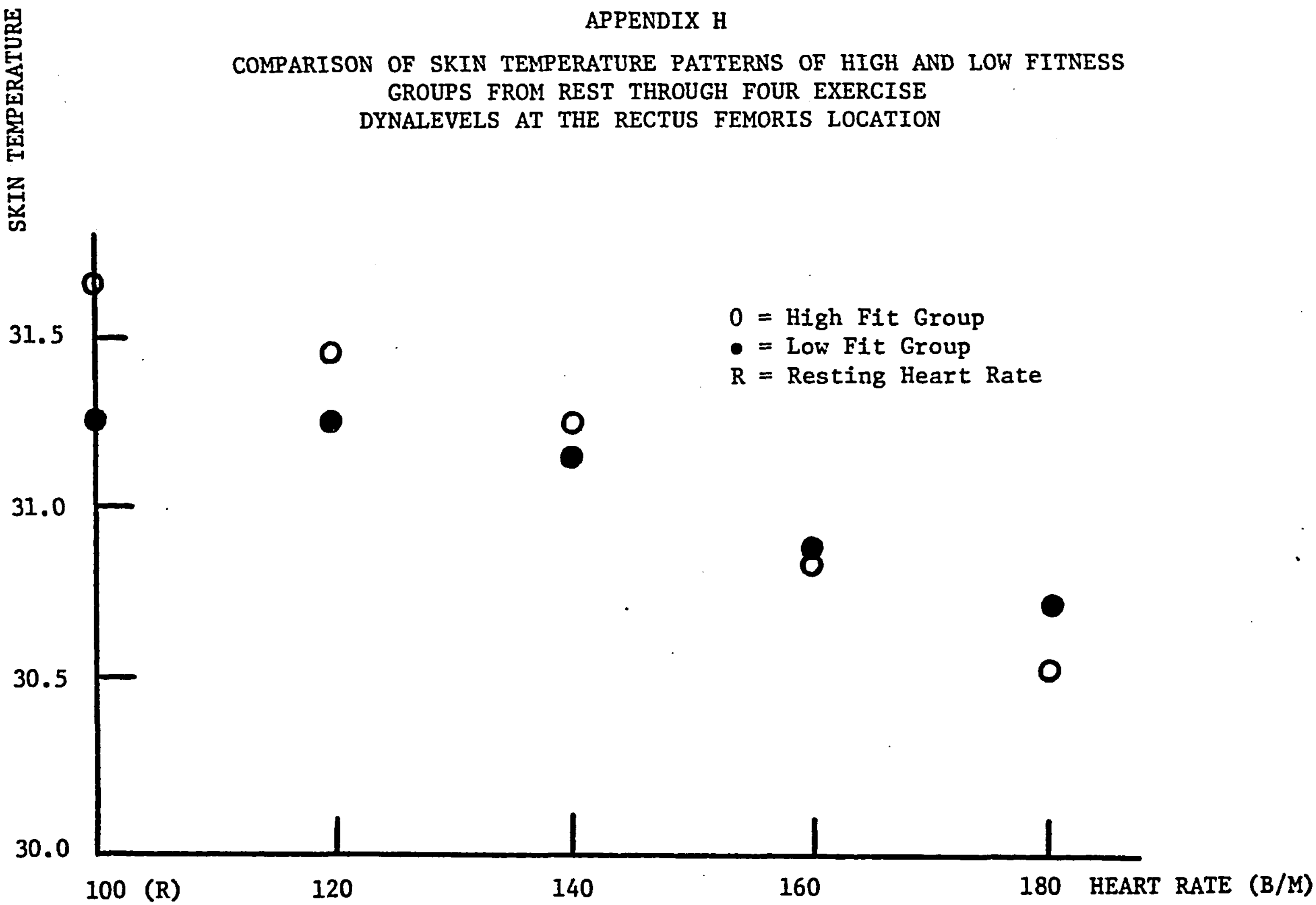
APPENDIX G

COMPARISON OF SKIN TEMPERATURE PATTERNS OF HIGH AND LOW FITNESS GROUPS FROM REST THROUGH FOUR EXERCISE DYNALEVELS AT THE BICEP LOCATION



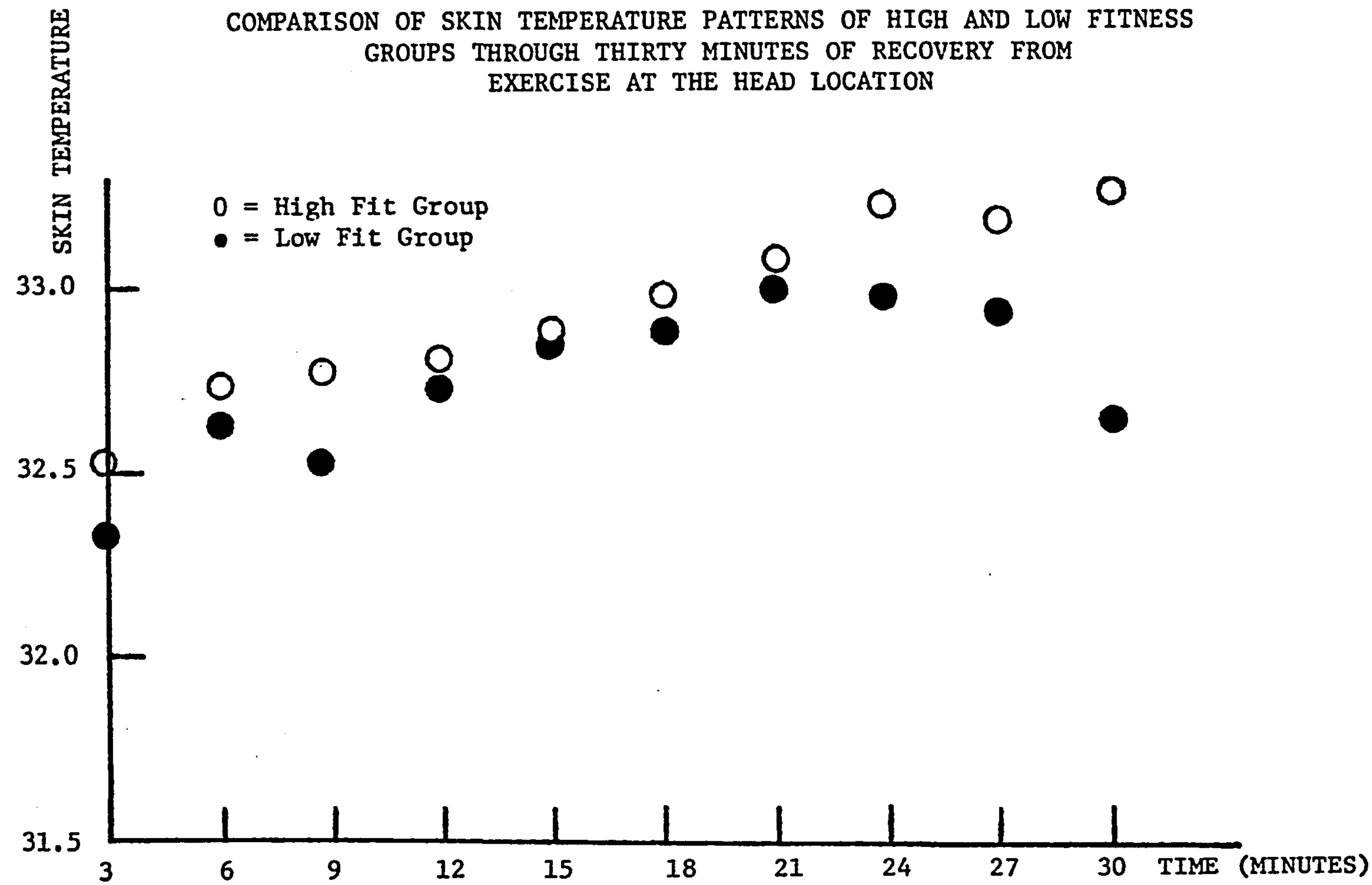
APPENDIX H

COMPARISON OF SKIN TEMPERATURE PATTERNS OF HIGH AND LOW FITNESS GROUPS FROM REST THROUGH FOUR EXERCISE DYNALEVELS AT THE RECTUS FEMORIS LOCATION



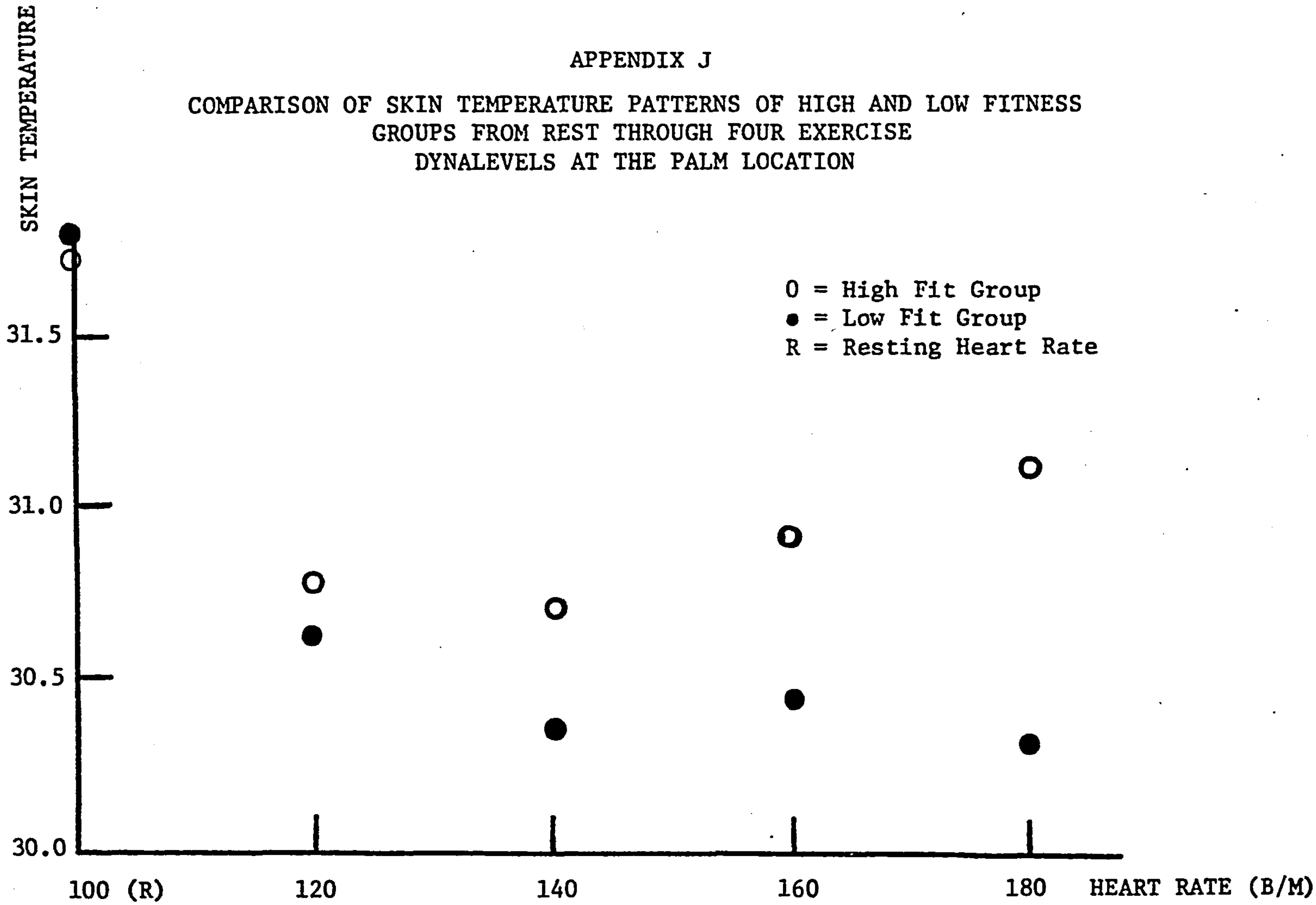
APPENDIX I

COMPARISON OF SKIN TEMPERATURE PATTERNS OF HIGH AND LOW FITNESS GROUPS THROUGH THIRTY MINUTES OF RECOVERY FROM EXERCISE AT THE HEAD LOCATION



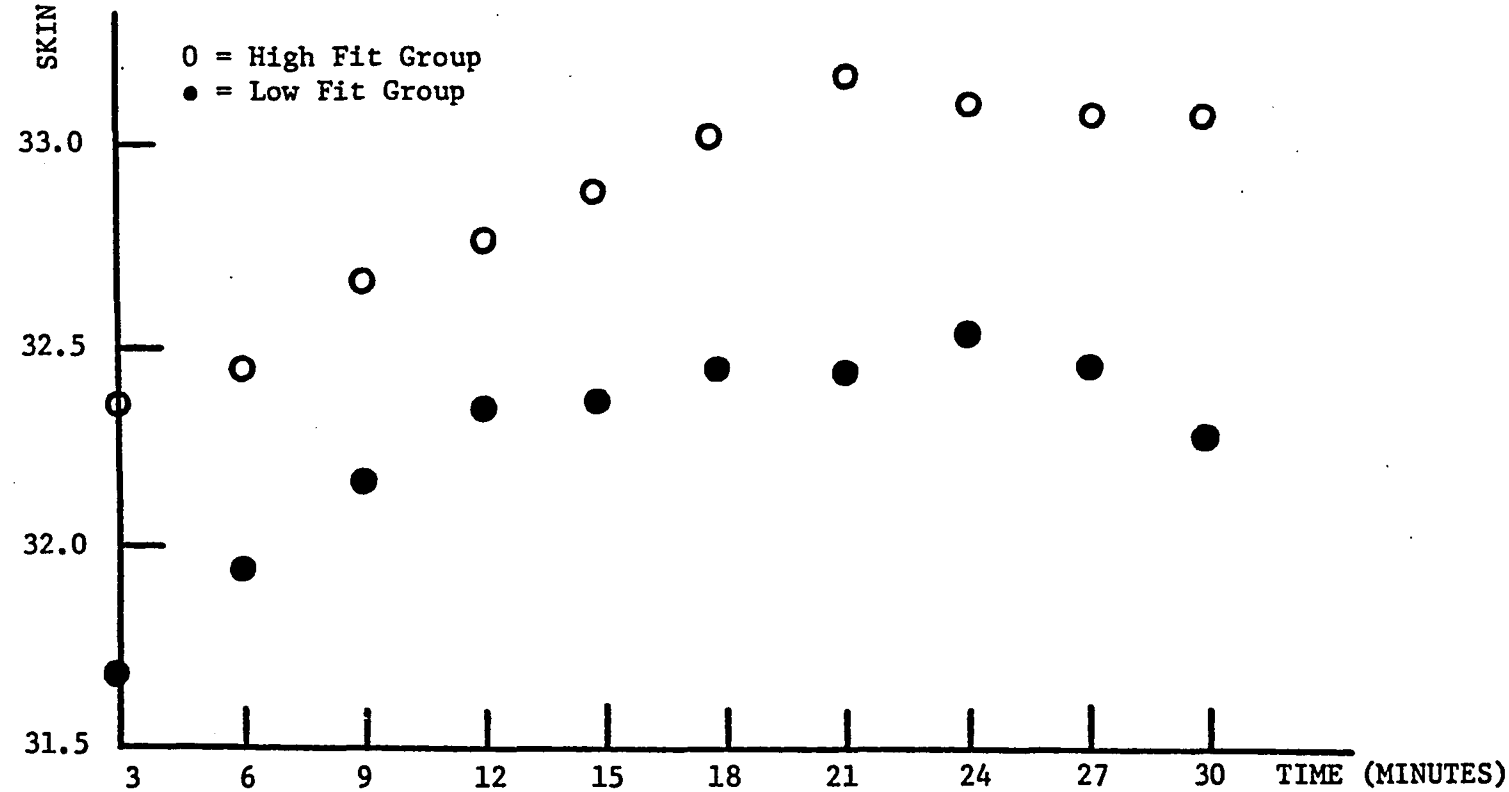
APPENDIX J

COMPARISON OF SKIN TEMPERATURE PATTERNS OF HIGH AND LOW FITNESS GROUPS FROM REST THROUGH FOUR EXERCISE DYNALEVELS AT THE PALM LOCATION



APPENDIX K

COMPARISON OF SKIN TEMPERATURE PATTERNS OF HIGH AND LOW FITNESS GROUPS THROUGH THIRTY MINUTES OF RECOVERY FROM EXERCISE AT THE PALM LOCATION



VITA

The author was born in Milwaukee, Wisconsin on March 7, 1941. He attended Jesuit High School in New Orleans and graduated in 1959. He earned a Bachelor of Science Degree with a double major in physical education and science in 1963, from the University of Southwestern Louisiana.

The author served in the U.S. Navy from 1963 through 1967 as a Lieutenant (junior grade) and served at duty stations in Morocco, Rhode Island, and Hawaii.

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EXAMINATION AND THESIS REPORT

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Major Field: Physical Education

Title of Thesis: Effects of Varying Exercise Stress Upon Skin Temperature During Exercise and Through Recovery

Approved:

Ralph E. Steben

Major Professor and Chairman

James G. Traynham

Dean of the Graduate School

EXAMINING COMMITTEE:

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Date of Examination:

November 25, 1974